FORM 113c, W. D., S. G. O.
(Revised June 13, 1936)
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ON THE

LIGATURE OF ARTERIES.

"IT IS NOT THE MAN WHO FORMS THE FIRST VAGUE NOTION OF A THING THAT REALLY ADDS TO THE STOCK OF OUR KNOWLEDGE, BUT HE WHO DEMONSTRATES ITS TRUTH AND ACCURATELY DETERMINES ITS NATURE."

Thomson's History of Chemistry, Vol. 2. P. 96.

"IF, UPON THE WHOLE, I MAY BE THOUGHT, BY COMPETENT JUDGES, TO HAVE SPENT MY TIME NOT ILL, I SHALL BE NO WAYS SOLICITOUS ABOUT THE OPINION OR EVEN THE CENSURE OF THOSE WHO CAN NEVER BE PLEASED WITH THE WORKS OF ANOTHER, AND YET WILL NEVER DO ANYTHING WORTH READING THEMSELVES."

Dr. Clifton's Trans. of Hippocrates, upon Epidemic Diseases. 1734. *Preface.*

A

THEORETICAL AND PRACTICAL

TREATISE

UPON THE

LIGATURE OF ARTERIES.

TRANSLATED FROM THE FRENCH, OF P. J. MANEC, M. D. PROF. OF ANAT.
AND OPERAT. MED. ETC. ETC.

By J. W. GARLICK, M. R. C. S. AND
W. C. COPPERTHWAITE, M. R. C. S.

WITH NOTES AND APPENDICES,

SELECTED FROM THE WRITINGS OF MANY CELEBRATED SURGEONS.

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ERRATA.

The reader is requested to correct the following errata which have accidentally occurred in passing the Work through the Press: a few typographical errors will also be found; but they have not been thought of sufficient importance, to demand particular mention.

Preface—page vii. line 15—for "than as earnest of the future and decided success" read "than an earnest of future and decided success."

Page 50 line 24 for "in" read "is."
59 ... 8 for "clear" read "clean."
66 ... 2 for "later" read "latter."
99 ... 11 for "latter" read "later."
137 ... 20 for "have" read "has."
161 ... 3 & 6 for "lung" read "pleura."
174 ... 29 for "5" read "6."
183 ... 18 for "Thus" read "There."
199 ... 5 after "takes the name of" insert "external iliac: afterwards."

ON THE LIGATURE OF THE PRIMITIVE ILIAC ARTERY.

Additional Note. On page 202, line 12, Manec states, "*I do not know any case of the primitive iliac having been tied.*" As this remark escaped the attention of the Translators when appending the notes in the body of the Work, they take this opportunity of correcting the error of his implication.—This artery has been thrice tied: once by Gibson; in this instance, the result was fatal. The second case was one of Professor Mott's: this surgeon was the "first who attempted this important operation on strictly scientific principles, on 15th March, 1827, for an extensive aneurism; and thereby saved the life of his patient; neither hæmorrhage nor gangrene supervened, and the individual was enabled to resume his usual occupation.

Crampton also has followed the example of this celebrated American surgeon: but the termination of the case was unfavourable: for the patient died of hæmorrhage on the fourth day. But notwithstanding, these very important facts were ascertained—that although the circulation, heat and sensibility of the extremity were momentarily suspended, they were soon perfectly re-established: every circumstance promised success; but these flattering hopes were suddenly destroyed by the occurrence of an apparent displacement of the ligature, and the supervention of the symptoms of internal hæmorrhage. After the death of the patient, upon a post-mortem examination being made, there appeared to be every probability, that the fatality of the case was attributable to the following cause: that the ligature of animal matter which Mr. Crampton had used, had been dissolved or ruptured, before perfect obliteration of the artery had taken place." Velpeau, vol. i. p. 188.

Bushe, of Philadelphia, has also performed this operation upon a very young infant, for a vascular affection of the labia pudendi. North of England Med. Journal. (Trs.)

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TRANSLATORS' PREFACE.

Numerous as the important subjects are which claim the earnest attention of the surgeon, there are few of the principles of which it is more necessary to obtain a right understanding, than those which should direct the application of a ligature upon an artery. The successful result of no operation is influenced to a greater extent, by the possession of accurate and precise notions, than the one which procures a safe, speedy, and effectual obliteration of an artery, by artificial or surgical means.

Notwithstanding the frightful mortality which for long periods must have attended the performance of the great operations in Surgery, and followed in the train of war, accident and disease, from sudden or long continued hæmorrhages, no systematic attempt, founded on the basis of anatomical observation, appears to have been made, to controul or prevent these disasters. Styptics and the actual cautery too frequently added to the list of evils which they were intended to prevent: or, if they did not increase, they failed to alleviate the sufferings and danger of the patient.

In the earlier ages of surgical practice, but after the ligature had been occasionally employed, although its value might be very partially estimated,

yet it was impossible that its use could be any other than empirical, the circulation of the blood through the vessels upon which it was applied, not being then understood. For a long period, even after the discovery of Harvey, were the true principles which direct its use buried in total darkness, which was not dissipated until that light beamed upon it, which began to dawn with the Science of the Anatomy of Organic Structure.

The vague notions of ages began to assume some degree of precision at the close of the last century, when Hunter, "guided by a deep insight "into the powers of the animal economy, substituted for a dangerous and "unscientific operation, an improvement founded upon those laws which "influence the circulating fluids and absorbent system"*—in applying a ligature upon an aneurismal artery at some distance above the tumour, the aneurism itself being unopened. The mode, however, by which the closure of the vessel was produced, was still not generally understood, "it "being supposed that the arterial parietes were merely approximated to "each other by the ligature, and that the obliteration of the cavity was "produced by their adhesion." "This doctrine led to a variety of inven- "tions for the purpose of placing a considerable extent of the opposite "sides in contact."† Of this, in common with many other remedies of Surgery, the practitioners of the close of the last, and especially those of the commencement of the present century, have had the honour of attempting to establish the scientific employment, and of endeavouring, by experimental enquiry, to ascertain a knowledge of what is always accomplished when a favourable termination is obtained.

A contrariety of opinion still exists upon this point, and as a consequence in the practice of the surgeon; continental and some British surgeons using

* Hodgson on the Arteries and Veins, p. 105. † Hodgson, p. 192.

compression to a greater or less extent, by ligatures of variable sizes, whilst others depend upon a dividing constriction alone.

The opinions which for some time, have been generally received in Britain on this head, are, that " instead of simply producing an approximation of the " opposite sides of the vessel, the application of a ligature to an artery is the " performance of a distinct operation upon it, producing a wound in its " internal and middle coats, which gives rise to an effusion of lymph, whereby " the opposite surfaces of the extremity of the vessel are united in the same " manner as soft parts, in general, are healed by the adhesive inflammation."

If it be admitted that a division of the two internal coats of an artery is necessary for its obliteration by the ligature, Dr. Jones possesses the merit of being one of the first in pointing out this circumstance, and confirming his views by experiments ; for although Desault was aware that such was the effect of the application of a single thread, he viewed this result rather as a cause of alarm, and an occurrence to be avoided, than as earnest of the future and decided success. Participating in these opinions, Scarpa proposed and practised a mode of operation, which, in principle, diametrically opposed that of our countryman. The former always being anxious to maintain the integrity of the middle and internal tunics of the vessel, and the latter equally desirous of destroying it. Scarpa's arguments have upon the continent maintained considerable sway, and produced some influence on the minds of our own surgeons, although the bulk of their practice favours the opinions which have been deduced from the results of Jones's experiments.

Notwithstanding, however, the decided preference which has been given to the use of a single thread, as a ligature, for the purpose of effecting a section of the two inner tunics, the precise mode is by no means unanimously determined, in which the successful termination of the operation is obtained ;

as to what conditions are essential, and what accompany, but afford no assistance in the closure of the calibre of the vessel. Is the clot, for instance, a non-essential? Jones makes the following remark; "But the formation "of this coagulum is of little consequence."*—"It seems to be entirely "owing to the effusion of lymph by which this adhesion is effected, that the "coagulum of blood, formed within the artery, is *sometimes* found adhering "by a small part of its *base* to the extremity of the artery."† Guthrie states that his "observations have *not led him to believe* that a coagulum is *absolutely* "*necessary* to the permanent closure of an artery—although it certainly assists "in maintaining it." Travers says, "I pass over the clot of blood, because "its presence is accidental, though not always unimportant;"‡ and again, "this "case exemplifies an accidental advantage to be derived from an internal "coagulum of blood,"§ or must Manec's opinion be received that its presence is an absolute requisite. "It hence appears, that a coagulum of considerable "size is absolutely necessary, for securing the success of the operation, when "performed upon a vessel of a large or middle size, as for instance, the femoral "or brachial arteries."‖

When taking a retrospective survey of any Science or Art, it is singular to observe, how slowly the ladder of Truth is ascended; especially when constructed upon the deductions obtained from the investigation of experimental phenomena. The observations which were first made upon the mode of effecting the obliteration of an artery by the application of a ligature, induced the belief that it was produced by the presence of the coagulum alone: but since the process of the adhesive union of a simple incised wound has been better understood, the opinion has been generally

* Jones on Hæmorrhage, page 160. † Ib. 160. ‡ Med. Ch. Trans. Vol. iv. p. 445. § p. 454.
‖ Vide Op. Seq. Part II.

received, as proved by the preceding extracts, that the closure is mainly attributable to the latter cause: and it will not be erroneous to say, that this has been accepted as the *sole* means of accomplishing this end; for a very eminent surgeon, who has been also just quoted, makes this assertion, that "the obliteration of an artery, tied with a round ligature, is "*only the cicatrization of this cut.*"* Manec, however, maintains that *both* these operations are required for securing effectually the success of the operation. The following opinions advanced by Jones, when treating upon this subject, so admirably anticipate any remarks which might naturally be advanced upon those differences of opinion, which often occur, even when the conditions which are their source correspond, that they do not require addition, and will not bear any subtraction. " It is obvious," he says, " that a connected series of observations can alone afford a full and " satisfactory view of the subject: such a series, whilst it confirms and " reconciles most of the facts on which preceding theories were formed, " will prove them to have been deduced from too limited an investigation: " and induce us to suspect, that, in some instances at least, their authors " have been influenced by a spirit of opposition and innovation, and an " unjustifiable propensity *to assign the whole effect to one circumstance alone,* " regardless alike of the observations of others, and of the general analogy " of the operations of the animal economy."

In the following translation, these principles appear to have been acted upon, and the deductions offered from numerous experiments which have been made upon this interesting subject, during a series of years, with the utmost care and minuteness of observation. Our author after having in the introductory portion of the work taken an anatomical survey of the parietes

* Travers. Med. Chir. Tr. Vol. iv.

of an artery; proceeds to point out, under the head of general principles, the mode which nature adopts for the obliteration of the arterial cavity,—the object to be kept in view in applying a ligature,—the relative value of the various kinds of ligatures; and, lastly, in the third or practical part of the work, developes in detail the anatomy of each artery individually, and describes the kind of operation which is best calculated for ensuring success, and securing those conditions the existence of which his previous observations have proved to be necessary. The whole being embodied, forms a complete treatise upon this special subject, which it is hoped will be favourably received by the profession; especially as the works of Jones and Hodgson have been some years out of print.

Truth, the aim and end of every scientific research, and more especially of that, the object of which is to render the most effective assistance under those imminent perils of life to which all men are exposed, can never be more effectually and rapidly advanced than by comparison, and the utmost freedom of enquiry; of every nation and every clime it stands forth pre-eminently beautiful when fresh chiselled from the mass of error, consfusion, or hypothesis, in which it is too frequently embedded.

In order to prevent the indulgence of any partial views, or the too ready admission of misinterpreted facts, it is very important to know the prevailing opinions upon the subject, in as much as they usually influence such as may have been immediately advanced upon the question, or have originated a certain series of experiments. The translators, therefore, being wishful to give the most complete and impartial exposé of which they were capable, and thoroughly unbiassed by any consideration of name or country, have felt it to be their duty to make very copious selections and extracts, not of paragraphs merely, but, in some instances, even of pages, from the writings of most

modern authors who have treated upon the ligature, which have been added to the original work, either in the way of note or as appendices. It will be scarcely necessary to enumerate the works of Cooper, Gordon, Guthrie, Hodgson, Jones, Lænnec, Lawrence, J. F. Meckel, Scarpa, Travers, Velpeau, and Thiorry, because each will suggest itself to the surgical student, as a source from whom information may be procured; and it is still less requisite to recommend a perusal of the original authors themselves. But whilst the observations of these gentlemen have been copiously extracted, and to that extent that a partial repetition of words may occasionally be found to occur, in every instance, each has been respectively appropriated to its author, in precisely the same terms in which himself gave it to the public: for the reputation of any editor has deservedly a short endurance if founded merely upon any self-appropriation of the knowledge of another, the property which himself possesses in it, depending only upon the title of having clothed it with a verbiage of his own.

The reader will thus obtain information of the notions entertained upon the subject by others, which he can use as criteria in forming his judgment upon those advocated in the text of the author; or, reversely, he can employ the text for the purpose of testing the opinions of others. The examination of conflicting opinions with each other is always beneficial, from the greater attention which they induce; and the very contrast itself will often point out a valuable truth, or detect a serious error, which otherwise might pass unnoticed: whenever, therefore, the statements made in the body of the work are contradicted, or rendered dubitable by a note or appendix which has been added, or when the contrary occurs, it must not be regarded as an accidental occurrence, but indicative of a fact, the existence of which is still uncertain, or which has now been incontrovertibly proved.

The translators, anxious to do some service to the profession to which they belong, are readily content to place themselves in the humble rank of those who are wishful honestly to diffuse correct opinions, from whatever source they may be derived: and, as comparatively few of its members have the opportunity, both from their situation and leisure, of making those experiments upon any particular subject, which will enable them to draw general and correct deductions, and moreover, as all men cannot fulfil offices of equal importance, they are encouraged to believe that in undertaking the humble labour which, in the present instance, they admit to have been self-imposed, they will be considered to have been not altogether negligent in performing the duties which they owe to mankind.

Halifax, 1st Nov., 1832.

PART I.

INTRODUCTION.

The human body is composed of various systems and organic apparatus: some of these, as the bones and muscles, determine its size and general configuration—some support these parts, by conveying to them elementary or molecular reparative principles—and others excite their action by communicating that power which is requisite for producing sensation and motion. Both the latter functions are performed by the nervous system, and its existence is so essential, that although the body possessed every perfection of structure, beauty, and symmetry of figure, and yet were destitute of this component part, it would be altogether defective as a living being, and as incapable of receiving the slightest impression from the external world, as of executing the most simple physical and moral action.

The circulatory system is the chief agent of nutrition—after having received the molecular principles that are prepared for the maintenance and increase of the animal organism from the digestive organs, it effects their combination, and conveys them into one common centre; thence, after being subjected to

the influence of respiration, and converted into blood, to be again distributed to every part of the economy with varying degrees of velocity. Physiology proves that nutrition is effected during the passage of the blood through the interior of the organs, at which time they select from this fluid the elements which are necessary for their reparation and increase, and the composition of their secretions.

If a body, therefore, be destitute of nerves, it possesses neither sensation nor motion; if the circulatory apparatus be wanting, it is incapable of developement and duration; the one being absolutely necessary for organic, and the other for animal life.* Since both orders of organs thus possess the highest importance, the physiological physician, as well as the scientific practitioner, must feel the deepest interest in whatever relates to the study of their organization, developement, functions, and diseases.

In the following work my researches extend only to the circulatory system, and even to this, only partially, as the aorta and the branches arising from its divisions, and subdivisions, to the fourth or fifth degree, are alone considered; but notwithstanding the limited range which this division bears with respect to the entire system, it exceeds in importance the whole of the remaining portions. The rich and vivifying blood which supports the vitality of every part,is directly transmitted from the heart into this division of the sanguineous system; and it solely contains the entire quantity of that portion of the nutritive fluid which is placed under the immediate agency of the contractive and moving power of the organ. If, therefore, the continuity of its parietes be destroyed by any rupture or wound, the loss of blood will take place with much greater rapidity than if the same accident occurred in any other part of the circulatory circle; and, as the life of the whole animal economy is maintained by its presence, the consequences of its escape will be instantaneously perceived.

* An exception, however, must be made of some classes of inferior animals, in which assimilation is performed, although they are apparently destitute both of vessels and nerves.

It must appear, therefore, from these remarks, that the discharge of arterial blood from its vessels, or in other words, arterial hæmorrhages, are accidents of an extremely severe character, and that if assistance be not promptly afforded, the life of the patient is placed in immediate danger. Hence, *Morand* has said, "If the cause of death in the field of battle be accurately ascertained, " it will be found that three-fourths of the sufferers die from hæmorrhage : " and, in the important surgical operations, an accident of this nature is " almost always of a formidable character."* Whatever then relates to the treatment of arterial hæmorrhage merits the surgeon's deepest attention. In the following work, I propose minutely to explain every particular and modification of the most valuable remedy which Surgery possesses for the cure of accidents of this nature—the ligature.

But before advancing any remarks upon ligatures themselves, it will be advantageous to make some general observations upon the form and structure of arteries, for the purpose of enabling such readers as are not familiar with anatomical enquiry, capable of appreciating the consequences which directly result from the use of ligatures of various kinds, and of tracing the progress of the consecutive phenomena which succeed their application with a degree of accuracy, not inferior to his who may already possess such information.

The Arteries contain the red blood, and form canals which extend from the left ventricle of the heart, to the capillary vessels. Anatomists usually describe them as bearing a general resemblance to a tree, the trunk being represented by the aorta, and its branches, by the very considerable number of ramusculi which this artery gives off. In considering the aorta as the arterial trunk, the branches which it furnishes will be distinguished into such as arise from it directly, being its divisions, and such as arise from these branches themselves, and constituting its subdivisions. The branches of the first, second, third, and fourth divisions, never communicate with each other,

* Mémoires de l' académie royale de chirurgie, tom. 12, p. 159.

the only exception to this general rule, occurring in the two mesenteric and vertebral arteries; but although the vessels of the extremities, which are of larger size, do not anastomose with each other, this is compensated by their becoming proportionately more numerous as they approach more nearly to their ultimate ramifications. The multiplication is so far continued as to form that perfect network in the substance of the tissues which renders it impossible to introduce the most sharply pointed instrument, without wounding a considerable number of these minute vessels and occasioning a discharge of blood.

Arteries do not possess the same structure throughout their course; or, at least, if they are composed of the same elements, these undergo peculiar modifications according to the capacity of the vessel which they form: for the organic layers, which are very visible and distinct in the larger trunks of the arteries, diminish in size and are found with difficulty, in proportion to their distance from the centre: and if they can be at all admitted to exist in the branches of the sixth or seventh division, the conclusion is rather an analogical than demonstrable result. We shall not occupy ourselves with any attempt to determine this point of anatomy accurately, but proceed to give a summary of the researches which have been made for the purpose of ascertaining the structure of arteries, as exhibited during the different ages of man and animals of different species. If the design of the work had not been strictly surgical, some remarks might have been offered in support of the opinion of Professor *Serres*, upon the analogy and resemblance which different arteries arising from the aorta bear to each other, but to treat of these facts of organic anatomy in the manner which they deserve, would lead us too far from the subject immediately in hand.* (Appendix A.)

* M. Serres has proved that every branch which arises directly from the aorta presents a similar series of rami; thus, if the branches produced by the divisions and subdivisions of a primitive carotid, a subclavian, a primitive iliac, and an intercostal artery, be compared with each other, it will be found that all these primitive trunks furnish nervous, glandular, muscular, and cutaneous branches; the only exceptions which occur to this rule being found in the trunks which he calls the digestive, viz. the two mesenteric, cœliac, and œsophageal

The parietes of an artery are formed of three layers or tunics: the first, external and of the nature of cellular tissue, unites the artery to the parts by which it is surrounded; the second or middle tunic is essentially fibrous, and gives to the artery that particular character which distinguishes it from every other vessel: lastly, the third is very thin, and lines the internal surface of the middle coat, and does not appear to differ from that which lines the interior of the veins.

Before commencing a particular description of each of these membranes, it must be observed that the principal arteries are inclosed in a kind of cellular canal, which has been designated by anatomists—the *proper sheath* of the arteries. The boundaries of the external surface of this envelope are not distinctly marked, a continuation with the surrounding tissue being formed by numerous processes, in such manner as to occasion great difficulty in ascertaining its commencement and termination: its internal surface, on the contrary, is very distinct from the cellular membrane of the artery. As these two parts are merely united to each other by cellular and vascular filaments, of an extremely delicate nature, their connexion is easily destroyed, a separation, in fact, taking place for an extent of several inches, if a very slight degree of traction is applied to the vessel in a longitudinal direction. A small quantity of serosity constantly bedews the tissue which is intermediate between the arterial sheath and its external membrane: this maintains the suppleness of the parts, and considerably facilitates their double motion, of dilatation and locomotion.

Arteries of the fourth or fifth order, as those of the fore-arm and leg, do not possess any distinctly marked proper sheath, and their external membrane has, consequently, a direct continuation with the surrounding cellular

arteries. The renal and spermatic arteries are purely glandular. The same Professor has also remarked that the connexions of the large arterial, with the large venous trunks, follow an inverse ratio, according as they are observed in the superior or inferior parts of the trunk. It is to be hoped that from these fundamental data some general principles, as to the relations which the arteries and veins of extremities bear to each other, will be deduced.

tissue. A knowledge of this fact will explain why the difficulty is greater of insulating small than large arteries.

Of the external Membrane. After what has been advanced, it will be supposed that the union of the external or cellular tunic of the large arteries, with their cellular canal, is feeble and uniform; whilst in those of smaller dimensions, it will be found to be very irregular, and usually much stronger. Arteries thus maintain a communication with the surrounding parts by means of the connexions which are formed with the external surface of their cellular tissue; and these almost exclusively maintain their vitality. This fact, however, will be considered afterwards.

The internal surface of the cellular, is very strongly united with the external surface of the middle tunic; it being impossible to trace any distinction between these two membranes, except that which is produced by a difference of structure. They are united by small and very numerous threads of cellular texture, which are inserted between the fasciculi of the most superficial fibres of the middle membrane, and are incapable of separation, except it be accompanied by their rupture. When it is attempted it frequently happens that a part of the superficial fibres of the middle tunic remains attached to the cellular membrane, and it thus becomes very evident that they only adhere to the cellular tunic by their middle portion.

I have observed that a peculiar layer is invariably present between the external and middle tunics of the aorta of the ox, which differs considerably from these two membranes, both in its component elements and structure. In the arch of the aorta it is very distinct, being at least half a line, and occasionally almost a line in thickness. Its rosy hue perfectly distinguishes it from the middle tunic, and an areolar structure renders it equally difficult to be confounded with the cellular membrane.

Small bodies of a greyish colour are placed in the areolæ, similar to those found in that portion of the fibrous tissue placed externally to the posterior part of the mucous membrane of the trachea; they appear of larger size, and

to be small glandular follicles. This layer is easily detached from the cellular membrane, but adheres very strongly to the yellow or fibrous tunic.

My researches upon this tissue, in animals of various species, have not been sufficiently extensive to enable me to state in which it is present or absent. In dissecting, however, the aorta of many human subjects, I have frequently and very distinctly found a layer situated intermediately between the cellular and middle tunics, and although I have been unable to detect any organization similar to that which I have described as found in the ox, it has corresponded neither with the external nor middle tunic.

The cellular tissue forming the external tunic, is composed of filaments which interlace each other in a felt-like manner, and adhere more intimately together in proportion as it is situated nearer to the fibrous tissue. Blood vessels very evidently enter into its formation; these are of two orders; one series arising from the artery itself upon the parietes of which it is distributed, and the other from the adjoining vessels: these constitute the *vasa vasorum* of the ancients. This membrane is also pierced by extremely minute filaments furnished by the grand sympathetic nerve. In the ordinary mode of dissecting an artery, nerves are not perceptible; but they may be rendered apparent by macerating for four or five days in dilute nitric acid, those portions of the artery upon which it is intended to experiment and demonstrate their presence. It thus appears that the external tunic of an artery is not characterised by any particular formation or tissue, which does not correspond with those usually possessed by cellular substance. Blood vessels and nerves are distributed generally throughout the animal economy: but the membrane, which is next to be examined, will be found to possess a different structure. (Appendix B.)

Of the middle or fibrous Tunic. This membrane corresponds, as was observed, with the cellular membrane externally and with the third tunic of the artery internally—and its thickness, when compared with the external and internal coats, is considerable: the disproportion however in this respect is not

general ; for whilst the tunic is very distinctly marked in arteries of considerable size, it gradually disappears in those of smaller dimensions. Its colour also varies with the size of the arteries, being yellow at the arch of the aorta, of a whitish yellow in the iliac and crural, and of a rosy tint in the small arteries. For the purpose of accurately exhibiting the imperceptible gradations of shade from one colour to another, which nature has produced, the aorta and one of its principal branches, as the iliac or subclavian, must be opened through their entire extent as far as their ultimate divisions.

The density of this membrane in large arteries is very similar to that of ligaments: it is always in the direct ratio of its thickness: its organization is very simple, being formed almost entirely of a peculiar tissue, and giving very trifling indications of the presence of cellular substance. This tissue, which for a long time has been regarded as muscular, is formed of curved fibres, which vary in length from one or two millimetres to two thirds of the circumference of the artery. The length of those most superficially placed is the greatest, and it gradually diminishes in proportion as they are more deeply situated or more nearly approach the third coat of the vessel ; in consequence, therefore, of this arrangement, they form concentric layers, which increase in length as they become more superficial. When a transverse section is made of the arch of the aorta, and it is examined either with the naked eye or by the glass, this fact may be very distinctly observed ; it will also be at the same time observed, that the extremities of these circular fibres do not terminate in the substance of the layer which they form, but that the whole bend inwards to the internal tunic, to which most of them adhere, after having passed between the fibres, or bundles of fibres which are placed below them. Those only which are placed superficially do not reach this point in a direct line, at least in a manner which can easily be recognised ; but intermix with the extremities of the deepest layer of fibres, upon which they are in reality inserted.

The extremities of these fibres which form the deep layers of the middle

coat pass directly to the internal tunic, but before coming into contact with that membrane, their direction is entirely changed, in consequence of a torsive motion, so that they no longer follow a transverse but longitudinal course: and when this is effected they cross each other, and thus assume the figure of a small hook.

It appears also in addition to this, that after the two fibres or small fasciculi have intersected each other, one extremity is turned either upwards or downwards, whilst the other takes an opposite direction: but, although I have never succeeded in carrying dissection so far as to trace a fibre throughout its entire course, I believe that this is an accurate description, because the thickness of the membrane is increased at the point where the direction of the fibres becomes changed. This is situated very near the internal surface of the middle membrane. Externally the direction of the fibres is transverse and curved, whilst internally it is longitudinal: and the length of the latter portion of the fibres, which have undergone this change, appears in a large artery to be one or two millimetres.

This arrangement can be very easily observed in the aorta of the ox, by macerating a portion in water for three or four days, carefully taking away the internal tunic, and then examining the fibrous tunic with a lens; small longitudinal striæ are then distinctly seen to be united laterally, and sometimes rather inclined towards each other: the presence of these striæ, or lines, has induced the most distinguished anatomists to believe that longitudinal fibres enter into the structure of arteries. In consequence of the intersection which has been described, the internal surface of the middle tunic is dissected with very great difficulty, and the vessel here receives a greater degree of firmness and compactness of structure, than can be found in any other part of its calibre.

From what has been advanced, it appears that the convex surface of the middle tunic of an artery, adheres to the cellular tunic by the middle portion of its fibres, and that it is united with the internal membrane by the inclined

extremities of these same fibres: thus, whilst the internal surface of the middle tunic derives great strength from this arrangement, the reacting motion which this membrane performs, in consequence of its elasticity, after having been distended by the blood, is materially facilitated. For this elastic power must of necessity be increased, and its action and developement assisted by the extent of insulation and freedom in which the middle portion of each fibre exists.

From observations which I have made upon the formation and developement of aneurisms in man, I have been induced to perform experiments upon animals, which prove that the internal surface of the middle membrane is alone capable of preventing an infiltration of blood, should any cause have destroyed the internal membrane.

Having laid bare the primitive carotid artery of a dog, compressed the lower portion, and placed a ligature upon its termination, the vessel was divided below this point, and a cataract needle introduced, with the point of which the internal tunic was torn through as deeply as possible, in several parts; the end of the artery was then tied, and the edges of the wound brought together.

Four days after this, a similar experiment was performed upon another animal, and the day after, both were killed.

When the dog was examined, which was experimented upon the day before, it appeared that the needle had produced several lacerations in the parietes of the artery. Some of these affected the internal tunic alone; whilst others extended to the deepest layers of the fibrous membrane; destroying and tearing through the intersection which is formed by the extremities of the transverse fibres. In the first instance, the blood had not penetrated the tissue, but in the second, the fibres of the yellow membrane were observed to be invariably infiltrated with this fluid; and in two points, the infiltration extended to the surface, which was probably attributable to the deeper penetration of the needle in these situations.

A similar infiltration of blood was witnessed in the other dog, but it was accompanied by a commencing absorption of the smaller coagula, which had

been formed in the adjoining part: no laceration of the internal tunic could be observed, some portions only of the membrane were thickened and appeared not to be so smooth and shining as the rest. I think that in these situations the internal tunic had been ruptured by the needle, and that the thickened portions were only cicatrices, or partial reproductions of the tunic. It will afterwards be shown that either state may exist.

It hence appears, that this arrangement of the fibres, composing the middle tunic of the arteries, (and which is now pointed out for the first time) produces two results: 1. That of increasing the elastic power of this membrane, by giving to each of the fibres a double insertion, at the same time leaving the middle portion in a state of perfect freedom: and, 2. That of opposing an insuperable impediment to sanguineous infiltration when the internal membrane is destroyed, by means of the intimate connexion of the extremity of its fibres, and the singular tortion which they undergo before they assume the longitudinal direction.

If the experiments which have been detailed appear insufficient to prove the latter fact, attention must be given to what is found to occur when an artery is affected by cartilaginous and osseous plates: for, notwithstanding that in these cases, the blood easily reaches the middle membrane in many points, by passing through the fissures which separate the morbid plates from each other, aneurisms are very rare, if the frequency of their occurrence be compared with that of arterial ossification; a sufficient proof that the mere contact of blood with the membrane, in an unprotected state, is insufficient for the production of an aneurismal tumour:* another circumstance being

* "Of all the causes capable of producing the rupture in any part of the proper coats of the aorta, especially the internal, I have great reason to believe that the slow morbid *ulcerated, steatomatous, fungous, squamous* degeneration of the internal coat of the artery, has a share in it much more frequently, than violent exertions of the whole body, violent blows, or an increased impulse of the heart. The artery is nourished, and increases in the same manner as all the other parts of the animal body; it is vascular and organized, and therefore must be subject to the diseases to which vascular and organized parts are liable. And it is a fact, of which no doubt can be entertained, that the proper coats of the aorta, and especially the internal coat, are subject from a slow

required in addition to this, viz. some effort which is capable of producing a rupture, or simple fissure in the internal surface of the fibrous membrane.*

The fibres of the middle membrane of an artery, are connected together by a very short and spare cellular tissue; which, though very apparent in its external layers, is distinguished with increasing difficulty as it approaches the internal surface. The membrane itself is brittle and easily broken by any bruising body. If torsion be applied in the transverse direction of its fibres, the internal surface cracks, and again offers a resistance: repeated efforts are necessary gradually to rupture its different layers, because the extensile power can only act first upon the deep, and afterwards on the superficial fibres. But if the same force be applied in the longitudinal direction of the artery, the internal surface is ruptured, and the portion which is experimented upon, divides at once, no repeated attempts being required. This is a necessary result, because in the latter instance, the fibres being merely placed in lateral juxtaposition, there is nothing to prevent the separation of the remaining portion, after the resistance, which is produced by their intersection, has been once overcome. (Appendix C.)

Although the structure of this membrane must possess vessels and nerves, anatomical research has failed to detect their presence: for these general systems, like that of the cellular tissue disappear, and are lost in a very considerable quantity of a peculiar yellow, or fibrous substance, which is

internal cause, to an *ulcerated,* and *steatomatous* disorganization, as well as to a *squamous* and *earthy* rigidity and brittleness. Read upon this subject what has been written by Bonetus, Lieutaud, Morgagni, Haller, Lancisi, by Guattani, Matani, Borsieri, Desault; and further, let any one skilled in the dissection of the human body consult his own observations, and it will appear that these morbid degenerations of the internal coat of the arteries are often, especially, in the curvature, thoracic, and abdominal trunks of the aorta." Scarpa on Aneurism. Wishart, p. 84. (Trs.)

* It may be here remarked, that spontaneous aneurisms in the extremities, almost invariably occur near the large articulations, as the shoulder, knee, &c. and also that arterial ossifications are less frequent in these regions than in any other portion of their course: it appears, therefore, the occurrence of aneurisms is not facilitated by the denudation of the middle tunic of an artery, but rather by that diminution of extensibility, which always accompanies the presence of cartilaginous plates, and the exposure to more or less severe extension, to which from situation it is liable.

characteristic of the arterial middle coat: they may be distinguished, however, at a very early period, if the tunic be examined before this substance is considerably developed, especially in the aorta of the embryo of the cow. In man I have only succeeded in injecting them in the two umbilical arteries. (Appendix D.)

Internal Tunic. This tunic presents, like both the others, an external and internal surface: the former is connected with the concavity of the fibrous membrane, to which it adheres, by means of a peculiar tissue which bears no analogy with the ordinary cellular texture: the latter is concave, and in perpetual contact with the blood: it is smooth, polished, and shining, like a serous membrane, from which, however, it differs in possessing a peculiar character, readily detectable by the eye. I refer to a villous appearance which is not found in serous membranes, and a degree of transparency very similar to that of ground glass; whilst this property, as exhibited by serous membranes, is exactly similar to that of common glass, which is somewhat dirty.

The difference in organization is not less striking. A serous membrane is composed of numerous filaments of cellular tissue, of an extremely delicate nature, which intersect each other: the internal membrane of an artery, on the contrary, examined even by the lens, presents no similarity to this; its appearance is uniform and distinctly formed of globular molecules, each bearing the same relative position to the other. When a portion of serous membrane is viewed under the microscope, it is also found to be composed of globules: but in this membrane their disposition is longitudinal, thus forming an elementary fibre, which, by an intersection with other fibres of similar structure, compose the web of these membranes.

It appears from these facts, that the internal membrane of an artery possesses a lower degree of organization than a serous membrane; that it is capable of less resistance, and that it is ruptured by the slightest traction: in this respect, as well as in the nature of its elements, it strongly resembles the membrane which forms the sac of small hydatids: for this, like the internal coat of an

artery, is always broken by the slightest effort; an accident which takes place in no other membrane except the retina. It would appear that the internal tunic of an artery, and the thin membrane of a hydatid, differ from each other in this respect only—a considerable quantity of albuminous serosity is interposed between the globules of the latter, whilst, between those of the former this fluid has no sensible existence.

Whatever be the identity and relation of the constituent molecules of the internal membrane of an artery, since it is invariably found to have a very low degree of consistency, and that it is ruptured by the slightest pressure, it cannot be supposed capable of increasing the resistance of the arterial parietes; and such, in reality, does not seem to be its intention, its use being to facilitate the progress of the blood through the interior of the arteries; a function which it the more easily performs because, in addition to the smoothness and polish of its surface, it is always smeared with an unctuous coating, which is readily perceived on opening an artery some time after death, and passing the finger over its internal surface. This operation very perceptibly detaches from the parietes a peculiar substance capable of very slightly soiling the fingers. The important office which it performs in the obliteration of arteries, will hereafter be explained.

I have performed some experiments upon living animals, for the purpose of elucidating the existence of this unctuous matter and its mode of production. The following plan was pursued, which enabled me to make these observations: 1. Having exposed the primitive carotid artery of a dog, and applied a ligature upon each extremity, an incision was made below the upper: the blood contained between the two ligatures was allowed to escape, and the vessel was even squeezed lest any portion should be retained; the extremity of the emptied portion was then tied. The same experiment has been frequently repeated both upon the dog and rabbit: the results have varied considerably, according to the species of the animal and the particular state of each individual of the same species.

When the dogs were examined, eight or ten hours after the operation, the unctuous substance which has been mentioned, was constantly observed to be accumulated in great quantities upon the internal membrane of the artery, (over which it was uniformly spread,) and was readily detached by scraping it with the tip of the finger. It always varied in quantity with the age and state of health of the animal.

In very young dogs, and such as were debilitated by abstinence, or any other cause, the quantity was less, more fluid, and less plastic than in those in an opposite condition; an exception, however, being made of old animals, in whom the results corresponded with those obtained from such as were younger but in an infirm state of health. A frequent repetition of the same experiment in the rabbit, has afforded a similar exudation, though of an inferior degree, the exhaled substance being less plentiful and unctuous than in dogs.*

In other animals, a portion of the artery was everted, so that the internal membrane was placed externally, prior to the tying of its open extremity: being thus exposed, a part was taken away and the vessel returned to its usual position; when it was examined, the unctuous matter was found not only upon the internal membrane, but the portion of the middle membrane which was denuded. When the experiment had been performed a few hours only, (eight or ten for instance) the unctuous matter which was collected within the artery possessed the same characters throughout; but at a later period, (thirty-six or forty-eight hours afterwards) its appearance and properties varied according as it was examined in the internal or middle membrane: on the latter, its quantity was much greater, its adhesion to the artery more intimate, and its consistency throughout more entire.

* As the quality and quantity of this substance, plastic or coagulable lymph, as it is called, varies both in man and animals, with the age and constitution of the subject, it explains why the ligatures of large arteries, unite more frequently in young subjects and persons of good constitution, than in those of feeble strength and advanced age.

From these experiments it must be concluded: 1. That the internal membrane of an artery is not the only source of the fluid by which it is lubricated: 2. That the middle membrane contributes to its formation, inasmuch as it appeared upon the internal surface of an artery, which had been deprived of its internal tunic. 3. That from the difference observed upon the examination of both of these membranes, the internal and middle, it must be said, that it is more plastic and easily coagulated when furnished entirely by the latter of these tunics. Its plasticity under these circumstances is so great, and its character when condensed becomes so similar to that of the internal membrane, that it is very probable that it reproduces the latter membrane, if from any cause it should have been destroyed.* This reproduction or compensation, however, is only effected when all the vital powers of the fibrous membrane are maintained: for, neither unctuous matter, nor plastic layer, is to be found upon those portions of the middle membrane, which form the interspaces, and separate the cartilaginous or osseous plates of a diseased artery from each other.

In its healthy condition, no vessels or nerves can be detected in the organization of the internal membrane of arteries. It may be supposed, from what has been said, that it does not possess any peculiar physical properties by which the power and resistance of arteries can be increased; for it is torn and ruptured by the slightest pressure of any substance.

It hence appears, that of the three tunics which form the arterial parietes, two, the internal and median, are divided and easily ruptured by any slight pressure or reaction: the external tunic alone directly opposes the force of any bruising bodies, whatever be the constricting power, and does not yield under any elongating force, until the other two have been some time ruptured. Cutting instruments alone are capable of dividing it at once, and without difficulty. (Appendix E.)

* These experiments have not been repeated sufficiently often to enable me to say that this reproduction positively takes place, but the probability of this is very great.

Having now ascertained the nature and particular arrangement of each of the three tunics of the arterial parietes, as well as the special characters of their vital powers, it remains to point out the resources which they confer upon the surgeon, when he is reduced to the necessity of effecting the obliteration of an artery: indeed, the phenomena which precede and follow the process, solely depend upon the properties of the parietes of these vessels. We shall proceed to shew that these phenomena or symptoms present numerous varieties, which are attributable, 1. To the size, form, and nature of the means employed in suspending the sanguineous circulation in the artery: 2. To the magnitude and particular state of the vessel.

To enable the surgeon to choose the kind of ligature which will best answer his purpose, it is necessary to detail the experiments which have been made on this subject. After *Desault* had proved that the internal and middle coats of an artery are always divided, when a ligature is applied and tightened upon it, several surgeons in common with this celebrated individual, were anxious to contrive some means capable of effecting an obliteration of the vessels, which, at the same time, would not cut through the membranes; hence originated the improvements and inventions of all the *presse-arteres* which were so highly extolled in France at the close of the last and commencement of the present century.* The invention of instruments of this

* "Aneurisms of various arteries have been cured by the steady application of pressure. Numerous and various modes have been adopted according to the parts in which the aneurism was situated. Sometimes pressure was applied to the aneurism alone, sometimes on both the aneurism and the lower portion of the extremity; or above and below the tumour. When the compression was applied to the aneurism itself, or both the aneurism and the extremity at the same time, it was generally effected by the external application of bandages of various kinds with the interposition of metallic plates: but if the artery was compressed above the tumour, it was usually bared and metallic instruments of different forms were placed upon the vessel in such manner as to maintain its two opposite internal parietes in close contact, without occasioning any rupture. These inventions were called presse-arteres. "Assalini's is nothing more than a small pair of silver forceps, the blades of which are broad and flat at their extremities, between which the artery is compressed. A spring composed of a piece of elastic steel, is attached to the inside of one of the handles, and by pressing against the opposite handle, retains the flat ends of the blade in contact. The spring is intended to be very weak in its

nature proved, that the notion entertained respecting the consequences of an application of a ligature to an artery were very indistinct—had this not been the case, they would have experienced but little alarm in cutting through the two internal membranes; nor would they have thought that this operation weakened the artery without forwarding the process of obliteration.

Bichat was influenced by this opinion when he said, "There can be no " doubt that no tissue is so fragile, if the expression may be allowed, as the " arterial, and consequently none which it is so improper to include in liga- " tures. How does it happen that this is the only one upon which it is " necessary to apply the ligature?"* In thus expressing himself, *Bichat* drew his conclusions from the immediate results of the ligature of an artery, as applied either upon the subject, or the living body. But he ought to have proceeded further: had he not neglected to trace the operations of nature step by step, and from stage to stage, he would have seen, that as the ligature makes a clean and regular section of the two arterial tunics, it induces the state which is more favourable for procuring an early closure, than those produced by instruments, which effect an irregular division of the same tunics, as broad and tape-like ligatures; or, than by those which merely approximate the opposite parietes of the vessel, as the *presse-arteres*. In the first instance, the wound has a simple character, and unites by the adhesive process: whilst in the latter, the parts are contused, and suppuration must take place before the adhesion of the lips is sufficiently strong to be capable of opposing the transmission of the blood: in the last case, the arterial parietes, being only approximated, the tunics are not in contact; moreover, the succession of the phenomena necessary for effecting an obliteration of the vessel, occurs only very slowly, and it always happens that the irritation produced by the

operation, but by means of a screw which passes through the handles, the pressure admits of being regulated and increased at the option of the surgeon." S. Cooper. See also his *First Lines*, Pl. I. fig. 3. See also Hodgson, p. 592. (Trs.)

* Anatomie générale, t. 2. p. 282.

pressure of the *presse-artere* upon the living tissue, is succeeded by that degree of suppuration which is destructive of the process which nature wishes to establish, for the purpose of attaining the object of the operation —obliteration of the artery.

In the ignorance or misconception of these facts, most surgeons have employed and recommended the use of broad and flat ligatures, and stated, that their size ought to be proportionate with that of the vessels. On this latter point, the error was extreme; for it will afterwards appear, that the use of small and round ligatures is essential in the large arteries, because the vitality of their parietes is less than that of the smaller vessels.*

When a principle is adopted which is erroneous, the conclusions drawn from it must be erroneous also; hence it is that *Scarpa*, who has performed such numerous experiments upon this subject, has invariably wandered from the truth.† He does not even attempt to tie an artery with a single thread, but always uses a broad ligature, and, at the same time, interposes between this and the artery, a body of considerable size, for the purpose of protecting its tunics against the destructive operation of the silk.

The serious accidents which this method entailed, induced this celebrated surgeon, who practised the plan, to recommend, some years afterwards, in a memoir especially dedicated to this subject, that all foreign bodies should be taken away at the termination of some days, so as to prevent that ulceration

* It is not intended, however, to advance this absolutely as a principle; but it is believed, that relatively with the size of the artery, it is more necessary to apply a small ligature upon a large, than small trunk.

"A question, no doubt, will be made here, whether it is safe to use these small ligatures on the large arteries; whether there may not be a risk of cutting the coats completely through? For we have been instructed to adapt the size of the thread to that of the vessel, and to tie a great trunk with a thick ligature. There is no reason for this rule, *prima facie:* we can only determine its justice by examining into the effects of different ligatures on the arterial coats. * * * * * * * * * * * * *

* * * If any proportion is to be observed between the size of the artery and the ligature, it should be an inverse one: the large one requiring a small ligature, while a small artery may be tied without danger with a large one. Lawrence. Med. Ch. Trans. vol. vi. p. 168. (Trs.)"

† Observations sur l' aneurysme, 1797-1798, translated and published by Professor Delpech, 1809.

of the artery which constantly occurred. The operations which are necessary in extracting this substance, are painful, because they are made upon a wound which is in a state of inflammation, and the edges of which are about to commence, or have already taken on the adhesive union: and they also expose the patient to the danger of direct hæmorrhage, from the disturbance and displacements which the vessel must undergo. In applying the ligature upon an artery, it would be infinitely preferable to use small bodies, the expulsion of which might, without any alarm, be left to nature to effect.

This latter mode of operation was proposed for the first time by an English physician, Dr. *Jones*, who, in 1805, published a valuable work upon the mode which nature adopts in restraining hæmorrhages. The numerous experiments which this skilful practitioner performed upon living animals, proved that, all things being equal, the success of the operation was more frequent and speedy, when the ligature was small and round, than under contrary circumstances. Although it is not strictly logical, rigorously, and in every case, to conclude from experiments performed upon animals, that similar results will take place in man, the analogy existing in the organic functions of animals of the same class is so great, that if the facts are not altogether opposed, we cannot but admit the similarity to be almost perfect.*

* "A variety of experiments have been made by different persons on the arteries of dogs and horses, in order to observe the processes which take place in them, to effect a cure, or which precede the dissolution of the animals. This has been done with a view of elucidating the manner in which these processes are supposed to take place in man, under similar circumstances: but the analogy, however specious, is not satisfactory, inasmuch as it is distinctly seen, that the injuries of arteries in man do not follow the same course as in animals: and the means which nature adopts to effect a cure of an injury in animals, cannot be considered to take place in man, as it is not followed by the same effects. This should not be regarded as in the slightest degree extraordinary, when we reflect that they are not liable to the same diseases: that there is a difference in the nature and in the coagulability of the blood, in the force by which it is impelled, and in all probability in the nutrition, if not in the formation or structure of the artery." Guthrie on Arteries, p. 209.

* * * General conclusions, drawn from the analogy, which is supposed to subsist between the arteries of quadrupeds and man, must be received with the greatest caution, since a few considerations will be sufficient to shew that this analogy is more apparent than real.

1. It may be stated in general, that the adhesive process is more quickly and certainly executed in all parts of quadrupeds, (with the exception of the skin) than in man.

An experimenter who is endowed with a philosophic mind will always know how to estimate the slight differences which he may observe. Under some circumstances they appear to be more distinct between two individuals of the same species, but of different ages and temperaments, than they are between those of different species, but which are analogous in age and constitution.

The advantages resulting from Dr. *Jones's* proposal were promptly seen and appreciated by several English surgeons, as *Abernethy*, *Cooper*, *Travers*, and many others, who did not hesitate in making its application to man. The most complete success crowned their attempts, and ere long almost every celebrated British surgeon adopted the plan. It was proposed, I believe in France only in 1814, when Professor *Roux* published a work* in which he drew a parallel between French and English Surgery: and when remarking upon the application of ligatures upon vessels, he mentions the method of Dr. *Jones*, but in that unfavourable and superficial manner, that it remained unnoticed; the proposal was in such low estimation that surgical works, of later date than that of Professor *Roux*, do not even refer to it.

At this period, two scientific experimenters, M. M. *Beclard* and *Breschet*, repeated and multiplied in numerous methods, the experiments of Dr. *Jones*:

2. In quadrupeds, wounds of arteries, in particular, are so prone to unite, that no experimentalist has hitherto succeeded in producing an aneurism in this class of animals; the wounds of the arteries which have been inflicted with this view, healing like wounds made in any other part of the body.

3. The arteries of quadrupeds are not liable to that peculiar change of structure from disease which predisposes to aneurism, and which, among other causes, renders the operation of the ligature so uncertain in its effect upon the arteries of man.

* * * It follows, therefore, that although in animals the obliteration of an artery should constantly succeed to the division of its internal and middle coats by a ligature, no conclusion should be drawn with respect to the effects of this operation upon the arteries of man. It is true that the experiments of Dr. Jones perfectly illustrate the process of nature by which the injury inflicted by the ligature is repaired; and it is true that this process is precisely similar, whether it occur in the artery of a quadruped or a man: but the *difference* is, that the process which is always successful in the former, not unfrequently fails in the latter; and it has been shewn that the causes of this failure are to be found in some difference in the structure or actions of the arteries in the different animals. Crampton on Aneurism. Med. Ch. Trans. vol. vii. p. 34. (Trs.)

* Relation d'un voyage fait à Londres. 1 vol. 8vo.

the results of which were so entirely in favour of round and small ligatures, that *Beclard* did not hesitate for a moment to use them in the human subject, with every benefit which he anticipated he should derive. A short time after this, some surgeons of the first rank, among whom must be placed M. M. *Dupuytren* and *Larrey*, particularly adopted this new method of operation: but other practitioners, who are also placed at the head of large hospitals, still continue to use the broad ligature; it thus becomes very difficult, if not impossible, for any one who has not personally experimented on this subject, fully to determine upon this extremely important branch of practical Surgery.

It may perhaps be said, that in consequence of the different plans of operation which the surgeons of the large hospitals adopt, the young practitioner must experience little difficulty in correctly appreciating the value of the respective modes, from the comparisons which he is thus enabled to make; but this mode of reasoning is incorrect: comparison is only advantageous when the circumstances are nearly the same; and it will be acknowledged, I believe, that several years may elapse without meeting in the Parisian hospitals with two cases of ligature of arteries which are identical, (if an exception be made of those which occur during the performance of amputation). Size of vessel, degree of vitality, age and constitution of the patient, and lastly, the relations which exist between the ligature and origin of a large collateral branch, are so many variable circumstances, which render analogies very rare, and therefore, comparisons very difficult to establish, and consequently, deductions from them uncertain. If, on the contrary, living animals be experimented upon, it is easy to perform two different experiments at the same time, upon the same animal, and upon similar vessels, as for instance, on the crural or carotid arteries: whatever varieties of result are then remarked, can only be attributed to the means which have been used: for in these cases, age and temperament of the individual, size of the vessel, and relative position of the ligature with the large collateral branches, are altogether the same. It must also be remarked, that

it is not a question respecting the analogy existing between animals and man, for an opinion has already been advanced upon this point, but rather to establish a comparison between two circumstances which are originally similar, and cannot present any differences except those alone, which the experimenter himself may think proper to make ; these are conditions which it is difficult to meet with in practice.

Great and almost insuperable difficulties have invariably compelled the surgeon to resort to the experimental plan, whenever he has wished to introduce into any scientific pursuit, some new proposal. Baron *Percy* has pointed out the same thing, when, at the close of the article upon the ligature in the *Dictionnaire des Sciences Medicales*, he concludes, "We would call the " attention of practitioners to this important but disputed branch of Surgical " Therapeutics, and urge them to repeat their experiments upon the two " modes which have been described,* and thus collect a mass of facts which " shall positively fix opinions which at present are wavering." With the intention, therefore, of dissipating this doubt and uncertainty, and of laying down one general rule of practice, a series of experiments have been performed upon living animals, and so arranged that, in the first instance, all those which have been suggested by others, to the present moment, have been repeated, and others which are entirely new, or modified, have been added.

I now offer to the public the result of these enquiries, and of many years labour, and shall be amply recompensed if the work in the least contribute to the success of some of the most important surgical operations, by rendering them less dangerous and uncertain.

The knowledge which the surgeon must possess, who has to perform the operation of applying a ligature upon an artery, may be divided into two kinds: 1. That which is general, and consequently applicable to every artery: it is thus indispensable for the surgeon to know what best conduces to effect a

* That of the broad and large, and of the small round ligature.

closure of the artery, and then to consider the means or agent which ought to be used for obtaining the desired result: 2. That which is particular or special, which is not only as variable as the arteries of one half of the body, but presents also differences according to the different parts of the same artery upon which the operation has to be performed.

The general knowledge may be modified by certain circumstances relating to the size of the artery and state of its parietes: it can only be properly acquired by experiment, because the observations made on the human subject have generally too great a difference to allow any just comparison to be made. The special knowledge can alone be acquired by the accurate study of descriptive and regional anatomy, which points out the frequently complex relations of each artery, with its surrounding parts. The general knowledge, therefore, relates to whatever follows the application of the ligature, whilst that which is special, is required for the exposure of the artery upon which the operation has to be performed.

In the first two plates of the work, the reader will find a faithful representation of the different appearances and alterations which the parietes of an artery, and the coagulum which is formed internally, undergo, from the period when the ligature is tightened to that of the closure, as well as of the differences which are produced in these changes, according to the nature of the ligature which is used. In the remaining plates are correctly represented the various arteries of the body which are capable of being tied—the relations of these vessels with the surrounding nerves, veins, and muscles are given, together with the figure and extent of the incisions which are most advantageous. The trunk and extremities are represented as placed in those positions which are respectively best calculated to allow the most easy performance of the operation.

Appendix A.—Page 16.

On the Analogy between the different Parts of the Vascular System.

One of the numerous results which increased anatomical information has produced, is the confirmation of the beautiful idea of the unity of organic composition. By the labours of modern continental anatomists, the science which they have cultivated has truly assumed a philosophic character, and no longer consists in a mere special description of parts, but in the developement of those general principles of beauty, order, and analogy, which, by their numerous researches, have been proved to exist in creation generally, and each animal individually.

J. F. *Meckel* ranks pre-eminent among his brethren for the extent and success of his labours upon this branch of scientific pursuit, and has devoted a considerable portion of his general anatomical work, to the consideration and elucidation of the facts upon which this theory rests. In this work, after making some remarks upon the elementary formation of the body, he proceeds to point out the unity which exists in the radiated structure of the different organs; the symmetrical construction of the different regions of the body; the analogy found between its right and left sides, the superior and inferior extremities, and the anterior and posterior surfaces; and the correspondences in figure and functions of the internal organs; and having shewn that in general the right is similar to the left half of the body, that the upper portion of the spinal column is represented by the lower, and that the single organs are themselves divided by a median line, in such manner that each half bears a general resemblance to the other, he proceeds, as follows, to remark upon the analogies of the vascular system.

"In accordance with a general law, the various parts of the vascular system bear an analogy, but do not perfectly resemble each other, in the three dimensions of breadth, length, and depth, of the vascular system.

The parts in which this analogy is the strongest, are the right and left halves of the system, the differences of which are only very trifling. Omitting all consideration of those which occur irregularly, the only inconsiderable difference is that which is found

in the disposition of the trunks which are given off to the head and superior extremities, from the arch of the aorta. This variety, however, appears to be only part of a general type which governs the whole arterial system : at least, it is frequently observed, that the superior aortic, intercostal, and bronchial arteries of the right side usually arise from a common trunk, in the same way that, in anomalous cases, several vessels are united on the right side into a single trunk, whilst on the left one trunk is divided into several branches. For example, the left carotid artery frequently arises from the innominata, instead of the left vertebral artery, which often arises from the aorta; the left renal artery also, is more frequently divided into several branches than the right; and in every instance in which I have observed the brachial artery to be divided very high, this was on the left side. The same remark is also correct with regard to the popliteal artery. The obturator is more frequently given off by the left than the right crural artery. When the arteria innominata, arising from the arch of the aorta, is divided into two trunks, it is very rare for the right subclavian artery to remain on that side : it is carried over to the left, and takes its origin from the left of the aorta, thus giving to this anomaly really the appearance of primitively corresponding with an extraordinary developement of the left, and the predominance of its type over that of the right side: the following circumstance strongly corroborates this conjecture : that, in these cases, the right subclavian does not pursue the most direct course, in passing to the extremity upon which it is distributed, but is deflected, so as to pass behind the œsophagus.

The characters peculiar to the two extremities are very frequently simultaneously developed beyond their usual degree. For example, the left carotid artery is a branch from the innominata, when the left vertebral arises directly from the aorta : or, the right and left carotids unite into a single trunk, when the right subclavian arises below the left.

The contrary appears to take place in the nervous systems : for the common left subclavian and iliac veins are much longer than the same vessels of the right side : and the superior and inferior thoracic canals of the left side unite together, whilst the superior of the left takes its course singly.

As for the remainder of their course, it is not unfrequently more symmetrical than usual, either by the union or division of the trunks, or that the customary position of

the vessel to the right or left side, is changed to that of the median line. Notwithstanding, the superior and inferior portions of the vascular system do not resemble each other so perfectly as the right and left sides; yet the analogies which they present far exceed their differences.

The diaphragm forms the separation between the superior and inferior portions of the vascular system: and, upon making comparison of each, from this point, we shall obtain the following results.

1. The great system of the circulation in the chest, like that of the abdomen, is composed of two other much smaller systems; the pulmonary vessels in the former, and the vena portæ in the latter cavity. The trunk of the vena portæ is an imperfect repetition of the right side of the heart; its arterial portion represents the pulmonary arteries, and the hepatic veins correspond with the pulmonary veins. The resemblance between the vena portal and the pulmonary systems is only very imperfect, in consequence of the former not being developed from a muscular centre, and because the portal veins anastomose with the veins in the general system. Nevertheless, these two conditions are met with, either single or combined, in the system of pulmonic vessels of most animals furnished with blood vessels, which are of an inferior order to birds.

2. The superior and inferior portions of the arterial system, are repetitions of each other, in the following respects:

a. The superior and inferior diaphragmatic arteries correspond.

b. The arteries of the alimentary canal, the cœliac, and two mesenteric, especially, correspond in their extensive anastomoses.

c. The bronchial arteries are represented by a portion of the renal and capsular arteries, and by the hepatic: in fact, the liver, supra-renal capsules, and kidneys, may be regarded as analagous to lungs in the abdomen, and hence, their vessels are repetitions of those of the lungs in various degrees of perfection. The vascular system of the liver, including the different vessels from the vena portæ, approximates very nearly to that of the lungs, although it is not near so perfect. The renal and capsular vessels occupy the next degree lower, for no trace of distinction between the nutritive and secreting vessels any longer exists: the separation, at most, being indicated in the kidneys, by some vessels which are different to the renal arteries,

and are distributed upon their surfaces, and in the supra-renal capsules, by a considerable number of vascular ramifications, proceeding from very different parts.

d. The thymic correspond with the spermatic vessels in this respect, that both generally arise from the aorta, and that the former may often arise from the bronchial, as the latter from the renal arteries.

e. The aortic intercostal are represented by the lumbar arteries: the number of the latter indeed is less considerable, but as the branches which arise from the middle sacral, which is itself a continuation of the aortic trunk, make them exactly correspond, all differences in this respect cease. The analogy between the arteries passing through the connecting foramina, above and below the diaphragm, is also remarkably strengthened by this circumstance, that the superior intercostal is a branch from the subclavian, in the same manner as the lateral sacral is from the hypogastric artery.

f. The division of the superior and inferior extremities of the aorta, and the disposition of the vessels which pass from it, from the one side to the head, neck, and superior extremities, and from the other to the pelvic organs and inferior extremities, present analogies still more striking. The primitive iliac corresponds with the common trunk of the subclavian and right carotid arteries: it is true, that the analogy is wanting in the right side; but in addition to this circumstance not being very essential, since it merely depends upon consecutive division, the analogy between the two regions is increased by the very common case, where the left vertebral artery arises directly from the arch of the aorta, between the left carotid and subclavian artery, whilst this anomaly, in some degree, effects the junction of the two vessels.

The carotid correspond with the hypogastric arteries: and the left subclavian with the crural, in respect to situation, origin, and distribution.

Of the trunks arising from the carotid and hypogastric, the superior thyroid and its branches, correspond with the uterine and vesical, and the lingual, facial, and ascending pharyngeal, with the internal pudendal and its ramifications.

The varieties which are observed in this respect, are the following:

The subclavian gives origin to the vertebral and inferior thyroid; the hypogastric to the gluteal and ischiatic arteries. The latter correspond with the branches of the

subclavian, and even the axillary, in their distribution. The former appear, in the first view, not to have any correspondence with the inferior vascular system, or with the vessels arising from the hypogastric artery. Upon consideration, however, the difference is almost reduced to nothing.

Indeed, it can only be denied that the vertebral and inferior thyroid arteries do not thoroughly correspond with the hypogastric. The carotids only represent a portion of the latter, which is considerably developed and reduced to a single trunk, in consequence of the greater size of the parts which it supports. The hypogastric artery then divides in the superior portion of the body into three trunks, the carotid, vertebral, and inferior thyroid. Hence, the reason why the inferior thyroid so frequently arises, totally or partially, either from the carotid or the innominata, or is altogether wanting, being replaced by branches of the superior thyroid. The origin of most of the vessels of the neck, and superior region of the shoulder, arising from the inferior thyroid, speaks much in favour of this approximation, because these vessels strongly resemble the gluteal, ischiatic, and obturator arteries.

The vertebral artery ascends from the trunk alone, in consequence of the size of the brain and spinal column, organs to which it transmits blood: but it evidently corresponds in its mode of distribution with the lateral sacral arteries, furnished from the hypogastric.

Several vessels which correspond, in their mode of distribution, arise superiorly from the subclavian, and inferiorly from the hypogastric.

The branches which next pass from the subclavian and crural arteries, possess the greatest degree of analogy to each other. The internal mammary exactly corresponds with the epigastric, as the former is distributed down over the lateral portions of the posterior surface of the sternum, and the latter posteriorly and laterally to the linea alba, which corresponds with this bone. The anterior intercostals, given off by the internal mammary, are represented by the analogous branches of the epigastric.

The circumflex iliac appears to me to correspond precisely with the long external thoracic.

The external pudics clearly represent several of the external thoracics.

In both extremities the trunk of the artery is divided, a short distance below the

articulation, into a superficial vessel which descends as far as the extremity of the limb, and a deep branch which does not pass beyond the first division, i. e. it does not go beyond the arm or the thigh.

Both circumflex arteries arise very high, sometimes from a superficial and sometimes from a deep trunk. They evidently correspond, in their relative positions, with the bone, and the first articulation of the limb, although their distribution varies somewhat in this respect, that those of the arm are distributed to the superior, and those of the thigh to the deep muscles, and that one of those of the arm is much smaller than the corresponding one of the thigh : the latter circumstance depends upon the greater developement of the muscles of the thigh. The first belongs to those higher branches, proceeding from the hypogastric itself, which are distributed to the muscles corresponding with those of the arm, which receive the blood of the circumflex arteries.

At the second articulation, the superficial brachial artery, like the crural, is divided on the surface of the flexion into two trunks, one of which immediately bifurcates in a very analogous manner ; the anterior tibial corresponding with the radial, the posterior with the cubital, and the peroneal with the interosseous artery.

The division, however, of these vessels presents a remarkable difference, that in the superior extremity it often takes place in a higher situation than usual, whilst this anomaly is very rarely seen in the inferior extremity, as instanced by myself and numerous other anatomists : for this difference it is difficult to assign a cause ; but the probable explanation makes it dependent upon the earlier developement, and nearer approximation to the heart, of the superior than the inferior extremities. It may also partially depend upon the great length of the fingers, the size of which, when compared with the back of the hand, is much greater than that of the toes, compared also with the dorsum of the foot, and they thus always appear considerably earlier than the latter. This anomaly, which is almost peculiar to the arteries of the superior extremities, should consequently have its source in the nominal disposition of the latter : in support of this conjecture, I must not forget to say, that an analogous difference is found in the disposition of the muscles of the fingers and toes, as the hand presents no appearance of the short extensors and flexors of those appendices which are found in the foot. It may be perceived also, with a little attention, that all the superior portion of the vascular system differs from the inferior in this respect, that

the separation of the carotid from the vertebral and inferior thyroid, the constant separation of the carotid from the subclavian on the left side, the frequent separation of the carotid from the latter, and the very common presence of a second inferior thyroid, are analogous phenomena, of which the lower extremities do not shew any trace.

The vascular system of the superior portion of the body is characterised by an evident tendency to individualization; but it is not the only one in which this is observed, for it may be instanced in the developement of the brain; the multiplication of the organs of sense, and the degree of perfection of the extremities, by which it is probably caused, and upon which it may depend.

The arteries of the inferior extremities have a character altogether different: the circumflex of the thigh are much more frequently given off by the crural profunda, than those of the arm by the brachial profunda. The superficial crural is not only never divided higher than ordinary, but the number of branches which the popliteal gives off, is frequently less considerable, because the peroneal or anterior tibial, the former much more frequently and much higher than the other, ceases to form a distinct trunk, and is replaced by the branches of one of the other vessels of the leg, as the fibula is to a degree only annexed to the tibia, whilst in the forearm, the radius and ulna are equally developed, and are each articulated directly with the humerus, precisely as the toes are much less perfectly developed and moveable than the fingers.

The articular arteries of the elbow and knee differ principally: 1. In this, that the superior of the thoracic extremities arise higher and always distinctly from each other, whilst those of the pelvic extremities originate lower, and usually from a common trunk: 2. That the inferior of the elbow arise from the artery of the forearm, and those of the knee from the inferior part of the popliteal artery. It is frequently found, also, that when the internal and superior articular popliteal artery arises very high, it always has two inferior popliteal articular arteries much smaller, which arise from the anterior and posterior tibial arteries, and occasionally, at least, the recurrent radial is furnished by the brachial. When the popliteal artery is divided a little higher than usual, both its branches also furnish two very large inferior articular arteries of the knee.

Many anatomists point out a difference in the distribution of the arteries of the hand and foot, from the want of the superficial arch in the latter; but I have never

thought this correct, and it certainly proves this, that sufficient care has not been used in ascertaining every analogy. There can be no doubt, that the internal plantar artery does not so much correspond with the superficial palmar branch of the cubital in its origin, as distribution. I have, moreover, always observed, that it anastomoses with the plantar arch of the anterior tibial, so as to form a superficial plantar arch.

But a real difference exists in the origin of the arteries of the fingers and toes, the former taking their rise from the superficial, and the latter from the deep arch. This irregularity of the vessels of the surface of the foot, is even sometimes developed to such a degree, that the arteries of the toes arise more from the superior than the inferior perforant artery. The object of such a disposition appears to be that of protecting the arteries of the toes from the superincumbent pressure of the body. It is also probably connected with the difference found between the dorsum and sole of the foot, with regard to its muscularity: and, perhaps, the developement of muscles upon the dorsum of the foot, which do not exist in the same part of the hand, is the reason why the arteries of the toes take their rise at a much greater depth. This difference, however, occasionally disappears, for in some cases the arteries of the fingers are furnished from the superficial palmar arch.

3. The veins of the superior and inferior portions of the body, resemble each other, perhaps, still more than the arteries; at least, the arteries present a variety which is not found in the disposition of the left jugular and subclavian veins, and that of the primitive iliac of the same side.

4. The superior and inferior portions of the lymphatic system offer also the same analogies, as to their existence, number, and situation of the vessels and glands.

The analogy of the vascular system, in common with that of every other part of the organization, is less anteriorly and posteriorly, than laterally, or in its superior and inferior portions. In this direction, however, the internal mammary and epigastric arteries may be compared with the aorta, and the branches which they send off to the posterior intercostals, and lumbar arteries: the anterior and posterior intercostals correspond as well as the anterior and posterior lumbar; this exists probably also in the neck and head, between the superficial and deep arteries certainly in these two regions and the spinal column, between the anterior and posterior spinal, as also between the occipital and frontal: lastly, in the extremities, between the anterior

and posterior circumflex of the humerus, the external and internal circumflex of the femur, the superficial and deep brachial and crural, the radial and cubital, the anterior and posterior tibial, the dorsal arches of the foot and hand, with the superior interosseous arteries of the palmar arches.

The venous system presents the same analogies, but which are rendered still more striking, by the presence of the vena azygos and demi-azygos, which very clearly correspond with the internal mammary veins.

With the grand thoracic canal, which takes its course anteriorly to the vertebral column, may equally be compared a second lymphatic duct, which rises behind the sternum."

Appendix B.—Page 19.

On the Cellular Coat of Arteries.

"The cellular is very thick, firm, and perfectly distinct from the fibrous tunic; and is much more extensible than the internal membranes." Manuel d'Anatomie generale, descrip. et pathol. par J. F. Meckel, tom. 1. p. 157.

"The *external or cellular tunic* is the only one which presents all the elements of a real tissue. It is composed of fibrillæ and lamellæ, intersecting each other like all cellular sheaths, in various directions, and is penetrated in every direction by very minute arterial and venous vessels, which, under the appellation of *vasa-vasorum*, support the whole of the substance of the artery, but neither pass into nor even extend as far as the internal tunic: this membrane alone, therefore, possesses a real circulation, nutrition in the others being only inactively performed, or when they are in a natural state merely maintained by a process of imbibition, or the simple deposition of molecules.

The structure of the external tunic endows the arteries with a great degree of extensibility, and enables them to give way under the application of any power, without

suffering rupture or inflammation, or producing cicatrization or adhesions to their envelope, or transmitting to the subjacent lamellæ, or even to their organization, the diseases to which it is specially liable: hence is the reason that in the vascular parietes of the capillary system, which are formed almost entirely of this substance, life is the most active and disease is the most frequent." Nouveaux Elemens de Médecine operatoire, par A. F. M. VELPEAU, t. 1. p. 51.

"The *external coat*, anatomically considered, is so simple, that many authors have thought it sufficient to say, that it is formed of condensed cellular membrane, which becoming gradually of a looser texture, connects the artery with the surrounding parts; but the importance which is attached, in a surgical point of view, to this coat, renders a more particular account of it highly necessary and interesting. Although ultimately resolvable into cellular membrane, yet it derives from the particular arrangement of its component fibres, a characteristic appearance, which distinguishes it from cellular membrane and entitles it to be ranked as a proper coat of an artery. Internally, or next to the middle coat, its texture is close and smooth, externally more open and rough, in consequence of the cellular membrane by which it is connected with an additional covering. The whole is remarkable for its whiteness, density, and great elasticity. If an artery be surrounded by a tight ligature, its middle and internal coats will be as completely divided by it as they can be by a knife, whilst the external coat remains entire; a fact which will be commented upon in another part of this treatise, and shewn to be connected with important circumstances. The strength, therefore, of an artery depends chiefly on its external coat, which answers, in some respects, the purpose of a strong fascia." JONES on Hæmorrhage and the Ligature, p. 3.

"The *external coat* of arteries differs extremely from the other two. It consists of slender, white, shining fibres, like the fibres of cotton, very dense and tough, closely compacted together, and interwoven in every direction.

It is best dissected by slipping the artery over a glass rod, so as to make it quite tight, and then tearing off the fibres with a pair of forceps, from without inwards. It requires considerable force to separate them: and no art will make them peel in any uniform direction. We judge that we have got through the whole of the coat, when

we come to a stratum of fibres, of a yellowish or flesh colour, soft, and separating uniformly in a transverse direction; these are the fibres of the middle coat.

Between the two coats there seems to be no connecting medium; but yet they adhere very firmly. The middle coat, however, is so much softer than the outer, particularly in vessels of a middling size, that if we slit up an artery, and strip it through between the fingers and thumb, we may scrape off the whole of the middle coat from the external, merely by pressing a little with the edge of the nail.

Numerous small blood-vessels may be seen, every where, ramifying through the external coat of arteries, and sending branches inwards to supply the middle coat. Small branches of absorbents, also, and minute twigs of nerves may sometimes be observed running along its outer surface; but it is difficult to trace them far into its substance.

The thickness of this coat varies much more than that of the other two. In some vessels, as in the *vertebral arteries*, and the branches of the *internal carotid*, it is as thin almost as silk paper.

It is greatly stronger than either the middle or inner coat, and considerably more elastic. To call this, however, or any other of the coats in particular, the elastic coat of an artery, as has been done by some,* is obviously incorrect. They all possess this property in a considerable degree; else, stretching an artery, should always tear them asunder." GORDON'S Anatomy, p. 60.

"The *external coat* is composed of a substance essentially distinct from the other two. Cellular and fibrous, the fibres interlacing with each other, without any marked regularity, although generally tending in a diagonal direction. It is capable of a powerful resistance to an opposing force applied in every way, and although highly elastic, seems to partake of a ligamentous structure. It is to this that an artery is indebted for its capability of sliding out of the way of injury: it suffers and resists a considerable degree of violence with impunity: and whilst the other coats are divided by the application of a small ligature, it remains unhurt, until inflammation occurs from pressure. If an artery be forcibly distended by an injection, the two

* See Mr. HUNTER, Treatise on the Blood, &c. p. 120.

inner coats are ruptured, but the external one is at first only stretched and dilated, but not torn, forming a kind of aneurismal sac. The external coat may be divided by the knife into two layers, apparently different; the inner layer, which is applied to the middle coat, is smooth and dense, differing from the external one in being more membranous, and not having its fibres obviously interlacing with each other as in the outer coat, although intimately connected with it." GUTHRIE on diseases and injuries of Arteries, p. 3 and 4.

Before *Scarpa's* observations upon this coat are given, an extract from the work just quoted, must be here premised.

"It is necessary, however, to observe, (says *Guthrie*, p. 67,) that *Scarpa's* account of the structure of arteries differs from that which is taught at the present day, so much as to render his description rather unintelligible to junior students. He considers an artery to possess only two coats, the internal and the fibrous, calling the elastic cellular one of ancient and modern anatomists, a sheath: and not distinguishing between that which is now called the outer coat, and the cellular tissue which surrounds and attaches it to the *real sheath* of the artery." His words are:

"The covering of the artery, which former anatomists, almost to the present day, have mentioned amongst the component coats of an artery, is by no means such as they have described it, but it is merely an adventitious sheath,* or cellular covering, which the artery borrows, or receives in common with the parts, in the vicinity of which it runs: by means of this cellular sheath the artery is kept in its place, as within a soft bed, and connected to the parts surrounding it, such as the membranes, the viscera, the nerves, the aponeurotic and ligamentous fasciæ, the muscles and periosteum. On cutting an artery across, in its natural situation, it is observed to be inclosed in a sheath of soft, spongy, easily distended cellular substance, within which sheath, the segment of the cut artery retires and conceals itself. This cellular sheath, most evident round the great arterial trunks, is in some places more dense and abundant, in others less so. It is found in considerable quantity, and very dense, round the curvature and trunk of the aorta, the carotid arteries, the

* MONRO's Works.—LUDWIG de arteriarum tunicis.—HALLER, Elem. Phisiol.—cellulosa adscititia.

mesenteric and renal arteries; but less so round the trunk of the brachial, femoral, and popliteal arteries. In all these parts, the cellular sheath, soft and easily distended, is only a continuation of the cellular membrane of the neighbouring parts. The pleura lies over the cellular sheath of the arch of the aorta, and over that of the thoracic aorta: and that of the abdominal aorta is covered by peritoneum. Both these smooth membranes surround and adhere closely to the aorta for two thirds of its circumference. The great arteries of the extremities, which run between the muscles, and under the aponeurotic and ligamentous fasciæ, are not covered, in addition to the cellular substance, by a smooth membrane, such as the pleura and peritoneum, but they are surrounded by a cellular sheath, which, although it is here and there filled with an oily substance, may notwithstanding be demonstrated to be distinct from the membrane properly called adipose, and which serves, as in the other parts of the body, to inclose the tube of the artery, and connect it to the contiguous parts." SCARPA on Aneurism, p. 69 and 71.

APPENDIX C.—Page 24.

On the Formation of Aneurism.

SCARPA states, (page 114. Ed. Wishart) "From all that has been hitherto said, with regard to aneurism in general, and more particularly that of the aorta, it appears to me that we may with certainty conclude: 1. That this disease is invariably formed by the rupture of the proper coats (modern internal and middle) of the artery: 2. That the aneurismal sac is never formed by a dilatation of the proper coats of an artery, but undoubtedly by the cellular sheath which the artery receives in common with the parts contiguous to it: over which cellular sheath the pleura in the thorax, and the peritoneum in the abdomen, are placed."

Upon this, *Guthrie* remarks also, "In regard to the two other conclusions of *Scarpa*, it is necessary to advert to his remark on brachial aneurism from a wound: when the

advantage which he has derived in argument, from the very general view which he takes of the external cellular coat of an artery, will at once be perceived." He says :

"The proximate cause, therefore, of the aneurism which is formed in the bend of the arm, after venesection, as also that which occurs in the brachial or axillary artery, produced by a wound, may *invariably* be traced to the incision or solution of continuity of the two proper coats of the artery, and the consequent effusion of blood into the cellular substance surrounding the injured artery. The effect is the same, whether from an internal morbid affection, capable of ulcerating or corroding the internal and fibrous coats of the artery, the blood be effused into the neighbouring cellular sheath surrounding the artery, which it raises after the manner of an aneurismal sac, or, the wound of the integuments having closed, the blood issue from the wounded artery, and be diffused in the surrounding parts. The solution of continuity in the integuments, cellular membrane, and aponeurosis covering the artery, consolidates quickly in these cases : while, on the contrary, the proper coats of the artery remain separated at the place of the puncture or wound ; and, therefore, as was observed by *Hildanus* and *Senertus*, the arterial blood not finding any longer a direct way to spring outward through the integuments, infiltrates as in the internal aneurisms produced by the ulceration or corrosion of the internal coat, into the cellular substance, covering, externally, the wounded artery, and fills it in the manner of an *ecchymosis ;* it then distends and elevates it in the form of a tumour, and the cellular divisions being destroyed, converts it at last into a firm capsular or aneurismal sac."

"The advantage of not having distinctly defined what he understood by the external elastic cellular coat, is plain. He alludes to it indifferently as a whole. Now when an artery is cut, not only in the loose cellular tissue divided, which *Monro*, as *Scarpa* observes, calls the "external loose cellular," but his "cellulo-membranous" coat is also cut, as well as the fibrous and internal coats : and the blood projected through this "cellulo-membranous" coat may be caught and retained by the external loose cellular, so as to form an ecchymosis : but it is a very distinct kind of ecchymosis from that which would have been formed in the same artery, if the fibrous and internal coats had been ruptured through disease. In this case the cellulo-membranous coat (according to the French writers) would have formed the sac. In the case of wound, it was the loose cellular tissue exterior to it and connecting it with the sheath. *Scarpa* contends

that the aneurism is formed in the same manner in both instances, which is most assuredly not the fact. The force of these and other objections have been so strongly felt by continental and other authors, who have admitted that he may be wrong in some instances, that they have ventured to say, he must have drawn his inferences principally from external aneurisms and not from internal ones. I shall not presume to say so much: but I must remark, that he seems to have seen all things with one view, and to have had the happy talent of making every thing suit his purpose, whether it really did so or not: and this too (I desire to be understood) with the most honourable spirit and intention."

To *Scarpa's* second conclusion it may be replied in the words of Mr. *Hodgson :*

"Aneurism is not constantly produced by the destruction of the coats of an artery. On the contrary, the inspection of innumerable preparations of this disease, contained in the principal museums of the metropolis, and the more minute examination, by dissection of various specimens of diseased arteries, and of aneurisms in the different stages of their formation, have produced a conviction in my mind, that, although in most aneurismal sacs, especially in those which have arrived at a considerable size, the coats of the vessels have given way, yet, in a great proportion of aneurisms, the disease commenced in a partial dilatation of the coats of an artery." p. 59.

He arrives, therefore, at the following conclusions:

1. "That numerous aneurisms are formed by the destruction of the internal and middle coats of an artery, and the expansion of the external coat into a small cyst, which, giving way from distension, the surrounding parts, whatever may be their structure, form the remainder of the sac.

2. That sometimes the disease commences in the dilatation of a portion of the circumference of an artery. This dilatation increases until the coats of the vessel give way, when the surrounding parts form the sac in the same manner as when the disease is in the first instance produced by destruction of the coats of the artery.

Aneurism, therefore, in some instances, originates in a destruction or laceration, and in others in a dilatation of the coats of an artery." p. 74.

"An aneurismal sac is formed by a new growth of the proper external coat of an artery, and it owes little or nothing to cellular structure, when little or none is supposed to exist." GUTHRIE, p. 71. See Article "Aneurism," S. COOPER'S Dict.

Appendix D.—Page 25.

On the Middle or Fibrous Tunic of Arteries.

"The fibrous membrane of arteries is firm, very elastic, of a reddish yellow colour, and distinctly formed of fibres placed transversely or, more correctly speaking, running in a direction partially oblique. They compose several layers easily separable from each other, but capable of being variously united together, so as to correspond with the arrangement observable in their separate fibres: they cannot, therefore, be reckoned as so many distinct tunics, as their structure is precisely the same, and as the number which can be exhibited depends upon the degree of attention with which their separation is effected.

This membrane is generally designated the *fleshy tunic*, from its fibrous structure and red colour: but the fibres are not similar to those of muscles, being more elastic, firm, fragile, dry and flat, than these: and, lastly, in having no cellular tissue whatever in their interspaces.

This is the thickest of the arterial tunics; and is the principal seat in which the great power of arteries resides. Its internal layers are more solid and closely set than the external; and its absolute thickness diminishes considerably as the distance from the heart increases. It is therefore greater, and the fibrous structure more apparent, as the arteries themselves are larger, whilst the proportional thickness increases in an inverse ratio: for the parietes become much stronger, regard being taken of their orifice and calibre, as the vessels diminish in size. It is also equally observed, that the membrane is redder, in the same proportion, and, if experiments may be depended upon, more irritable also.

But the thickness of this membrane varies so considerably, both in different parts of the same artery and in different parts of the arterial system: in the first case being always more considerable at the convexity than concavity of the arterial curvature and in the angles of their divisions, than in the other parts.

In the second case it must be remarked:

1. That the thickness of arteries is less considerable in the interior of the viscera than muscles, and in the loose than the attached portions of the vessels.

2. That the cerebral arteries differ considerably from the others in the thinness of this tunic, the tenuity of which is so considerable that its presence has been doubted, but erroneously. The absence of this tunic occasions their collapse when empty, their greater liability to rupture during life, and the facility with which the circulation is perceived through their parietes. This tunic is much thinner and more extensible in the pulmonary than the aortic system.

Some anatomists think, that the internal fibres of arteries are longitudinal, obtaining this opinion either by applying deductions made from animals, or from a wish to satisfy purely theoretical opinions. Longitudinal fibres, however, do not exist." MECKEL, t. 1. p. 157.

"The middle, which is also called the muscular, albugineous, and yellow tunic, is formed of incomplete fibrous circles, and not of longitudinal fibres, which are united by lamellæ and filaments of the same nature. Neither sanguineous nor lymphatic vessels can be found in it, although some have maintained the contrary. It forms an almost inert layer, and breaks brittle like glass when twitched by a thread, and suffers rupture instead of distension, when any eccentric force is applied, which exceeds its natural power of resistance. Possessing elasticity like the yellow tissue of the trachea and interlaminary ligaments of the vertebræ with which, to a certain degree, it corresponds, it is impossible to tear it away in a direction parallel to the axis of the artery without rupture. Externally it is united with the cellular tunic by means of an irregular lamellated substance, which scarcely possesses organization: and internally it is similarly connected with the internal tunic. As it is deprived of sensibility, and almost of every other property of animal substance, it is not surprising that the diseases to which it is liable are mostly independent of vital phenomena, and seem to develope themselves under the agency of laws which govern inorganic matter. This coat forms the distinctive mark between arteries and veins, enables them to continue open when cut transversely, determines their figure and colour, renders them so little liable to inflammation, prevents their wounds or partial divisions from cicatrizing by agglutination, and occasions them power, fully able to resist the lateral impulsion of the blood. It is thickest in those portions of the arterial trunk which are nearest to the heart, and most considerable where it is subject to the strongest impulsion of the

blood, being also rather more abundant in the convexity than concavity of the arterial curvature. When it reaches the branches of the fourth or fifth order, and the ultimate ramifications of the vascular system, it gradually becomes more tenuious, and intermingles with the common tissue of the other two tunics; the consequence is, that the suppleness and extensibility of arteries are greater, and their liability to rupture less, *(cœteris paribus)* in proportion, as their size is diminished, and their distance from the heart is increased." VELPEAU, t. 1. p. 49.

"The *middle coat*, which is the thickest, is formed by numerous layers of firm, compact, fleshy fibres, of a pale red colour, passing in a circular direction, but appearing rather obliquely connected and interlaced with each other, than forming complete circles. These fibres are of a peculiar nature, are well supplied with nerves, and resemble, in form and disposition, muscular fibres, but differ from them in possessing a remarkable degree of elasticity. Their elasticity keeps an empty and dead artery open and circular; for this coat, when detached from the internal and external coats, still preserves the cylindrical form, whilst they, on the contrary, in a state of separation, become flaccid and collapse. As this coat has no longitudinal fibres, the circular fibres are held together by a slender connection, which yields readily to any force applied in the circumference of the artery. The middle coat is intimately connected with the internal and external by very short and fine cellular membrane." JONES, p. 2.

"The *middle coat* of an artery is the thickest; being about twice the thickness of the outer one: and this proportion, it seems to me to maintain, in the smaller as well as in the larger vessels.

It consists of a stratum of slender fibres laid closely together, side by side, without any intermediate connecting matter; and placed uniformly in a circular direction, surrounding the artery, and in a plane perpendicular to its axis.

Those which are more internally situated, may be easily seen through the transparent inner coat of the artery, by slitting up the vessel. If this coat be peeled off, the fibres of the middle one may then be easily raised by the forceps in successive strips, all of which separate in a transverse or circular direction, exactly like the outer bark of a birch-tree.

In the large arterial trunks the fibres are firmer in their consistence, and of a

yellowish or straw colour; but as the vessels diminish to a middling size, they become gradually softer and more flesh-coloured, and then resemble, very much, the muscular fibres of the heart.

The middle coat of an artery is abundantly supplied with small blood-vessels. They are often seen turgid with blood, after death; and they easily admit of being injected with coloured size or turpentine. I cannot say that I have ever seen either absorbents or nerves in this coat.

No connecting medium can be perceived between the middle coat of an artery and the inner one. They are merely laid over each other, as the inner membrane of the ventricle is laid over the muscular coat of the heart." GORDON, p. 58.

"The *middle coat* adheres intimately to the internal coat, and is composed of circular, flattened fibres, disposed in layers, and united to each other laterally by smaller ones passing obliquely between them. The circular fibres do not extend completely round the artery, they rarely, indeed, form more than half a circle; and are conjectured to be the seat of its contractile, the oblique ones of its elastic properties. It is more natural to suppose they are common to both, although acting in different directions with various degrees of power; the enlargement or diminution of an artery being comparatively greater than its extension. The circular fibres are easily separated from each other by dividing the oblique ones, and the whole forms a strong, dense, elastic, although brittle coat, of a yellowish white colour, thicker than the remaining tunics conjointly. In the aorta it is very thick and may be separated into several layers, which diminish in number as the artery passes to the extremities; where it seems to form one fibrous expansion, stronger perhaps in proportion to the size of the vessel than in the aorta itself. This fibrous structure is said to extend even to the most minute vessels, although it is not easily demonstrated. In the arteries of the brain it is exceedingly thin, so much so, that its existence has been denied. It is through this coat the artery preserves the nearly circular appearance which it presents when divided in the dead body: it is, therefore, highly elastic as well as contractile, both longitudinally and transversely. No longitudinal fibres can be discovered, although their existence has been asserted, and it is possible that the folds seen in the inner membrane may have given rise to this speculation." GUTHRIE, p. 2.

Appendix E.—Page 28.

On the Internal Membrane of Arteries.

"The *internal membrane* is much thicker, less transparent, firmer, and more brittle than the other portions of the vascular system: it is not very extensible, and its density is very considerable. In several experiments which have been performed upon dogs, when the outer and middle coats have been taken away, and the arteries deprived of all protection from the surrounding parts, neither rupture, nor distension of the tunic has taken place." Meckel, t. 1. p. 154.

"The *internal tunic*, which by some has been compared to a mucous membrane, and by others to a serous membrane, is smooth, its free surface being usually lined by an unctuous substance. Externally, it adheres to the middle tunic merely by fine lamellated plates, which contain neither vessels nor any other organized element: it possesses neither fibres nor vascular canals of any kind whatever, it is merely a a lamellated homogeneous substance, a kind of glared substance not dissimilar to the transparent cornea, or the matter which forms the nails or the horny tissue in general, and facilitates the course of the blood through the whole arterial tree. As in the smaller and capillary branches this tunic is not separated from the cellular by the middle membrane, it assumes more decidedly the character of an organized body, its external surface receiving fluids in the direct course of circulation: elsewhere it is thicker and more distinct, but extremely fragile, and separated throughout, from the other parts of the vascular system by the yellow tunic, it there only forms a simple inorganic layer, similar to cartilage, possessing very little elasticity and very easily ruptured. From possessing these characters, it results that this membrane is not endowed with the nature capable of undergoing a primary inflammation; and that it can only be affected by this pathological phenomenon by its communication with the surrounding tissues: in a word, that any changes effected in it are only mechanical." Velpeau, t. 1 p. 50.

"The *internal coat*, although extremely thin, is very close in its texture, and gives to an artery a smooth and polished lining: considering its delicate structure, in the longitudinal direction, it is elastic and firm, but so weak in the circular as to be very easily torn by the slightest force applied in that direction. The morbid changes which have been observed in it, prove that this coat is vascular:* and some experiments have been related to shew the probability of its being sensible."† JONES, p. 2.

"The *inner coat* resembles, exactly, the inner membrane of the ventricles of the heart. It is equally thin and perfectly transparent and colourless; and its inner surface is smooth. No vessels or nerves have yet been seen in it. It may be peeled off from the middle coat, which it lines internally, by means of a dissecting forceps: but it is too tender to separate in large patches. It differs from the inner membrane of the ventricles in being a good deal more elastic." GORDON, p. 58.

"The *internal coat* is, in the aorta, composed of several layers. In the extremities it is a single membrane, of a smooth or polished appearance, of a whitish yellow colour, partly transparent, without fibres, soft and unctuous to the touch, of a dense, elastic, resisting, membranous structure, although by a slight degree of extension readily torn in every direction. Neither vessels nor nerves can be traced into it in its natural state, although their existence is proved by its capability of undergoing the various processes dependent on inflammation. It is sometimes seen in the carotid and iliac arteries, disposed in longitudinal plaits, as if folded, instead of having contracted in the diminution of size of the artery. In the ham, and at the elbow, these little folds or ridges are placed transversely; and, in an artery torn or divided during life, this appearance is always observable, and it performs probably an important part in the suppression of hæmorrhage." GUTHRIE, p. 1.

* "I have more than once observed the cavity of a large artery almost blocked up by a steatomatous thickening of this coat, and frequently I have observed purulent matter collected in it." ALEX. MONRO. Ed. Med. Es. & Obs. vol. ii.

† BICHAT, Anatomie Generale.

"The *internal membrane* of an artery, although very thin, being, however, very compact and smooth, is that which opposes the greatest resistance to the impulse of the air, (under artificial inflation) and prevents, more than any other, the bursting or preternatural dilatation of the arterial tube. As soon as the internal coat of the artery is ruptured, the muscular coat is likewise ruptured, or is immediately torn, and allows the air or any other fluid, injected with force into the tube of the artery, to flow into its external sheath." SCARPA on Aneurism.

PART II.

GENERAL PRINCIPLES.

To produce complete suspension of the circulation of an artery, is the first indication which must be fulfilled towards effecting its obliteration. The modes by which this may be accomplished are various: 1. The vessel may be merely flattened, its opposite parietes being placed in contact with each other, but without lesion of its tunics: 2. The artery may be flattened or puckered, the internal and middle membranes being ruptured partially: 3. The artery may be uniformly drawn together, the internal and middle tunics being cut through in a clear and regular section. (Appendix F.)

For the purpose of avoiding useless and tedious repetitions, we shall in the first place describe the changes which take place in an artery when it is no longer permeable by the blood, in consequence of the gathering together, or forced approximation of its parietes, its internal membranes being divided in an even manner. This case has been intentionally selected, because it is followed by a greater number of phenomena, the succession

and various changes of which take place more rapidly, and exhibit more marked characters than those of others: the description, therefore, of these being once given, when the first and second modes of suspending arterial circulation are treated upon, it will only be necessary to adopt the subtractive method of proceeding. This I am aware is not an usual or generally a logical method, as it is better to pass from the simple to the compound, or to make addition; but in the present case, I believe that greater advantage will be obtained by pursuing the opposite course in consequence of the difficulties of ascertaining and describing direct phenomena when studied in the most simple cases.

As an artery cannot be tied until it has been exposed and separated to some extent from the surrounding parts; it becomes necessary to consider what mode should be adopted in performing this first step of the operation. Prior to the commencement of any other proceeding the surgeon should select and conveniently arrange the instruments and other apparatus which he may require: these are bistouries with straight and convex cutting edges; scissors of various shapes; dissecting forceps; flexible and inflexible grooved directors; blunt and sharp pointed probes, which ought to be flexible, and capable of receiving any shape which may be most convenient; curved needles having blunt points and edges, similar to those used by Baron *Larrey;** *Deschamp's* needles,† or those having handles, with lateral or anterior curvatures, such as are always used in England; and, lastly, the ligature which is to be applied to the vessel.

The requisite apparatus are few: fine sponges; waxed threads, which are sometimes required to tie such vessels as may be wounded during the operation; some strips of plaster; lint; pledgets made with holes and

* Curved needles ought not to be used for sutures, being dangerous to the parts upon which they are employed.

† When Deschamp's needle is used, its curvature ought not to exceed the 4th of a circle and it should likewise possess a spiral figure.

covered with cerate; several other common compresses of different sizes; thread; pins, and several vessels containing water.

When these have been arranged in such order as the operation may require, the surgeon, with the aid of his assistants, must place the patient in that position which he considers the best calculated for enabling him to apply the ligature. This being done, and the patient supported by those appointed for the purpose, a skilful assistant having compressed the principal artery of the limb upon which the operation is about to be performed, the operator by means of a convex edged bistoury makes an incision through the skin, which ought to be as parallel as possible with the direction of the artery, its length varying in proportion with the depth of the vessel which it is intended to lay bare: generally speaking, there is less error in making the wound longer rather than shorter than what is necessary: if it be too small, the operation is rendered more tedious and painful, in consequence of the greater difficulty experienced in reaching and insulating the artery: the liability to inflammation and more extensive suppuration is also much greater under these circumstances than when the wound is very large. Having divided the skin, the subjacent parts may be cut through by a second stroke of the bistoury, without any fear of danger, if the vessel be deeply situated, a fact which it is always easy to ascertain. On the contrary, if only a thin layer of cellular tissue and some aponeurotic threads are found laying between the skin and artery, which is frequently the case, great caution must be used not to injure those parts which it is important to preserve. The subcutaneous laminæ must in this case be raised with the forceps and opened by dedolating* a portion with the bistoury held in a flat position, then introducing a grooved director through the aperture they must be divided above and below until the incision is of an equal extent with

* This word is introduced because it has no single equivalent expression in our own tongue—"*Dedolation*," in French, signifies "The act of cutting any body obliquely with a sharp-edged instrument, so as to produce a wound accompanied by loss of substance. (Trs.)

that in the skin. This being done, it is necessary that the same precautions should be used in opening the proper sheath of the artery, which connects it with the adjoining parts. It is, however, not only unnecessary but would be dangerous to make the size of the incision equal to the others, because by so doing the arterial parietes would be rendered liable to an inflammatory attack; its extent ought not, therefore, to be greater than what is required for enabling the operator to separate the artery without difficulty from the accompanying vein and nerves: the probability of a consecutive inflammation of the extremities of the artery (an accident which may occasion the most fatal consequences, as will afterwards be shewn) is diminished in proportion as the insulation of the artery is small: the same reason which renders it dangerous to open the cellular sheath of an artery requires that it shall neither be displaced nor raised with any greater violence, by the ligature, or any other body by which it is surrounded or supported, than can possibly be avoided.*

A disregard of this recommendation often entails most dangerous consequences; for the cellular and vascular bands which connect the surface of the vessel with the interior of its proper sheath are thus sometimes destroyed: and when this occurs the artery becomes (in effect) a foreign

* As our Author's opinions differ in some degree from the deductions made by Dr. Jones, it may not be irrevelant to suggest the inquiry how far these discrepancies were occasioned by the neglect of a due observance of the precautions respecting the displacement and separation of the artery from its sheath, during his experiments, to ascertain the natural means of restraining hæmmorrhages. The attention of the reader is directed, particularly to the mode in which *Jones* drew out the artery from the wound by the ligature, and to the consideration of the effects which such violence must have occasioned.

Let the reader refer to the details of exp. 2, page 30, (Jones) and its dissection, to exp. 5, 11, 12, &c. (and it may be fairly supposed that throughout the whole of that section a similar method of experimenting was followed inasmuch as the contrary is not stated) and he will then be able to reconcile the statements respecting the coagulum and arterial parietes given in pages 45 to 145 with those of our Author.

From the details of exp. 13, page 153, it appears to be placed beyond a doubt that little or no care had been taken in the previous experiments to avoid the violent insulation of the artery from the surrounding parts, and consequently the correctness of the deductions respecting the invariable existence of the coagulum is materially shaken. (Trs.)

body surrounded by living tissues. The only connexion, indeed, which it holds with the rest of the organism, is by its continuity, and if under these circumstances the patient is neither young nor of good constitution, and the performance of the operation has been difficult, there is great probability that the artery will not unite with its sheath by the adhesive process, but that suppurative inflammation will be developed between the parts. In every instance this separation is invariably injurious: because should it even not be followed by suppuration, it constantly impedes the progress and succession of those phenomena which must take place in the two extremities of the vessel, before its closure is perfectly established.

When an artery is insulated within its sheath, its vitality is materially diminished, and it may be reduced by this kind of artificial means, even in a young and vigorous individual, so as to be placed upon an equality with that of a similar vessel in an aged person, but which has maintained its adhesion entire. This, however, will be considered again.

So soon as an artery is completely insulated for a short distance, the surgeon must pass the ligature around it, if he intend to tie the vessel: or place the *presse-artere* upon it, if he merely wish to flatten it. Whether *Larrey's* needle, the needle-pointed probe, or the hafted needle be used, when the artery is situated by the side of the vein, it is better to introduce the instrument between the vessels so as to make it protrude on the opposite side, and thus more certainly avoid the possibility of injuring the vein. Should it, however, be situated posteriorly to the artery, this vessel must be raised in a very gentle manner, and the threaded instrument cautiously glided under its posterior surface. Displacements of the vessels to this small extent may be effected by means of a pair of dissecting forceps, and a grooved director, or the ivory handle of a scalpel. One of the vessels is seized by the forceps and thus drawn to the right or left side, whilst with the instrument, the other is pushed in a contrary direction; similar care must be taken in separating the artery from the surrounding nerves, but

instead of including the nerves in the forceps, they must only be turned on one side by the director ; for any compression of these cords produces very great pain, and frequently occasions a spasmodic contraction of the part to which they are distributed, an accident which the surgeon will always be anxious to avoid.

After the thread is placed under the artery, the ends hanging out of the wound, the surgeon must take them in one hand, and apply a gentle traction so as merely to support the vessel, whilst with the indicator of the other hand he compresses the artery against the doubling of the thread by which it is supported, and at the same time orders the assistant to discontinue his pressure upon the artery. If, during this procedure, the hæmorrhage or pulsations of the artery, below the part compressed, do not re-appear, there will be every certainty which can possibly be had, that the operation will prove successful. Finally, before the first knot is tied, the surgeon must again assure himself, for the last time, that he has not included either vein or nerve within the ligature ; being satisfied in this respect, a single knot must be made and lightened in a degree proportioned to the effect which he is anxious to produce ; namely, the section of the internal and middle coats of the artery or the maintaining of their integrity : but whatever be his aim, he must use every precaution whilst tying the knot, neither to raise nor drag the vessel from its situation : this he will accomplish after having brought the knot to the vessel by introducing his thumbs or indicator fingers, if the wound is deep, between the threads and drawing them in opposite directions, by placing the nails of each finger against the other : having made the first knot, the assistant must place his finger upon it so as to prevent it giving way, when the second should immediately be tied. Every surgeon is aware that there is no utility in tying several : and it has also been equally well understood, for a long period, that what was formerly named the surgeon's knot is not only useless but inconvenient.

When the artery has been thus tied, the wound must be united by the

adhesive process; and, in order that as small a foreign body as possible may be left in it, one end of the ligature must be cut off close to the knot, the other must hang dependent from the wound, to facilitate the withdrawal of the knot, upon its separation from the artery. This is a precaution which must never be omitted, for should the parts cicatrize before such separation has taken place, abscesses will afterwards form until it is expelled. (Plate I. fig. 7.) (Appendix G.)

In the course of my experiments I have frequently employed ligatures of various animal substances; as silk, catgut, nervous filaments, tendinous fibres, threads of untanned leather of different sizes, made of sheep or rabbit skins; but immediate union has never been effected upon these foreign bodies, without being afterwards succeeded by abscesses for their escape. I am aware that celebrated individuals and accurate observers, have published facts which are at variance with this statement, but I am the more inclined to maintain this opinion, because I know that it is entertained by several Parisian surgeons, and amongst these, by Professor *Dupuytren*: this talented practitioner has constantly observed the union of the wound to be retarded, purulent accumulations being formed until the ligatures were entirely expelled; which is sometimes not accomplished until two or three abscesses have succeeded each other.

Two facts of the nature may be here instanced: the first was observed in a young fox, the primitive carotid artery of which was tied with a silk ligature, and the wound united by adhesion. Six weeks after the operation, a large abscess formed in the course of the vessel; when it was opened, and the interior examined, the knot of the thread was found attached to the parietes: it was easily extracted; and there can be no doubt that if it had not been taken away, or naturally expelled, by this suppurative process, other abscesses would have been formed until this was effected. The second case occurred in a large dog: in this instance, the axillary artery was tied, and a silk ligature used. This animal suffered under three abscesses in the axilla

for a period of five months after the operation : had I been able, as in the fox, to perceive the ligature, the two later collections of pus would have been avoided : but this was prevented by the depth of the wound. When the first abscess was healed, a portion of indurated cellular tissue, of the size of a pigeon's egg, was found an inch and a half, or two inches deep, which necessarily resulted from the presence of a small foreign body. At the termination of the second abscess, the remaining induration was scarcely equal to the size of a nut, and as the depth below the surface of the skin was only a few lines, that which subsequently took place, easily expelled this body.

Similar results as decidedly take place when other animal substances are employed, as ligatures for the vessels, as when silk is used, if neither of the extremities are left out of the wound, to allow their withdrawal, as soon as loose : the most rational treatment, therefore, consists in always uniting the wound at once, so as to obtain as perfect union by the adhesive process as possible, but the surgeon must not neglect to make the number of the ends of silk, hanging from the wound, correspond with that of the ligatures. When the dressings are applied, these threads ought to be enveloped in a piece of fine linen, that any dragging may be avoided ; they should then be placed in the most dependent part of the wound, or what is preferable, that situation should be selected which will place them in contact with the living tissues to the smallest possible extent. Having used this precaution, the wound must then be dressed, the edges brought together, and maintained in apposition with slips of adhesive plaster : they must then be covered by an open compress spread with cerate, upon this a slight pledget of fine *charpie* must be placed, an ordinary compress upon that, and the whole retained in its situation by a gently applied bandage. The first dressings, like those of simple wounds, ought to remain undisturbed for three or four days.

Having explained the rules and plan which are to be followed in applying a ligature upon arteries in general, we must next describe what takes place

in the wound, and point out the course which nature pursues in effecting an obliteration of these vessels: and it will appear that the phenomena which are developed, both within and around the artery, present very great differences, *cæteris paribus*, according as small and round, or broad and large ligatures are applied, or the *presse-arteres* employed.

Description of effects produced in Arteries, by the application of small and round Ligatures. The first operation of the thread is to produce a puckering and approximation of the arterial parietes to each other. When they are in contact, and the ligature is again still further tightened, the internal and middle membranes of the artery are divided by a clear and even section, and the cellular tunic itself, which, by the powerful pressure of the ligature, has been the direct means of effecting this, resists its operation: the superior and inferior lips of the section of the internal tunics retracting at the same time, the cellular membrane is alone included in the ligature, the divided internal membranes being directed inwards above and below the thread, on the one side towards the heart, and on the other towards the capillaries. The consequence of this is, that the arterial cavity above and below the ligature assumes a conical figure, the apices of these cones being formed by the lips of the divided internal and middle tunics, prevent the transmission of blood beyond this part, which then beats against the cellular tunic. In this point, then, the entire power of the ligature is concentrated, for the lips of the divided internal tunics are only approximated and held in mutual contact by the pressure or constriction exercised upon them by the external tunic, by which their edges are inclined towards the centre of the vessel. At the same time that this moderate and steady pressure is sufficient to produce a closure of the arterial calibre, it is effected in such manner as not to impede the progress and developement of the vitality of these two membranes: that portion of the cellular tunic which the ligature exclusively surrounds is destroyed, and suppurative inflammation is developed for the purpose of causing its detachment, together with the ligature from the living

parts. In this manner the ligature ultimately effects a complete section of the vessel; the internal and middle membranes being cut through instantaneously, whilst the external or cellular tunic is only divided at a later period. (Appendix H.)

The effects which take place in arteries by the application of a ligature shall now be specially described. It has been stated that the internal and middle tunics are completely divided, (Pl. I. fig. 1, *b*,) and that when the ligature only acts upon the cellular tunic, the lips of the section of the two former membranes are in apposition with each other, (Pl. I. fig. 5, *d*,) an accurate idea of this may be formed by examining this figure. Although the vessel is opened, it will be very readily seen, that when it is closed the lips of the division of the internal membranes must be in contact with each other. Such being the situation of the parts, the following changes are produced. At the termination of eight or ten hours, (it may be rather sooner or later, according to the state of the individual and the artery,) a quantity of thickened albumen, or coagulable lymph, according to some authors, exudes upon the divided surface of the internal and middle membranes, and unites these parts together; and almost immediately after its first appearance, a gradual increase in its quantity and consistency begins to take place. The column of blood which is incessantly impelled against the obstacle by which its further transmission is prevented, deposits some fibrinous filaments, forming the first rudiments of a coagulum: the combination of the concrete albumen and this rudimentary coagulum, unites the divided edges together, but in a manner so feeble that the slightest motion of the parts is sufficient to produce their separation. When some time has elapsed after the operation, for instance, twenty-four or thirty hours, the appearances vary: the quantity of the newly formed substance has increased considerably, and its organization becomes considerably developed: so that at this period, the filaments have obtained sufficient strength to maintain the lips of the small wound in approximation, when the artery is opened throughout its whole calibre. (Pl. I. fig. 5, *c*,)

Whilst this advancement in organization takes place, the coagulum also increases in size; during the first periods of its appearance, (usually about the sixth or eighth hour,) it is represented by two, three, and sometimes a greater number of small mamillary eminences,* which are soon united into one mass: this usually occurs in fifteen or twenty hours. Up to this time the coagulum does not entirely fill the cavity of the artery: the blood can still pass between the surface of this body and the interior of the vessel, and thus beating against the cul de sac, formed by the internal and middle tunics, the small coagulum which is attached by its base to this part is constantly moved by the impulsion of the fluid. (Pl. I. fig. 5, *b*: fig. 3, *b*.)

This condition is maintained for a short time only, for the cavity of the artery is gradually filled by the constant deposit of new molecules on the surface of the coagulum (Pl. I. fig. 1, *c*: fig. 7, *c*, etc.); but its developement always takes place first in length, and then in thickness. This assertion is proved by the observations which have been already made, and also the consequences which result when a ligature is applied too nearly to any large collateral branch. Under these circumstances the size of the coagulum is only equal to the filling of the vessel for a certain distance from the base, being considerably attenuated in the remainder of its length. (Pl. I. fig. 1, *c*, *e*.) In those instances, where the collateral branch is still nearer, than in the preceding cases, the coagulum continues loose, and floats through the whole length of the arterial cavity. (Pl. I. fig. 6, *d*.)

Under this condition of the parts, although the blood continues to reach the bottom of the artery, by gliding over the coagulum, the impetus is insufficient to wash off and take away the unctuous matter which constantly exudes from the internal membrane: but, on the contrary, this substance being secreted more copiously than under the ordinary state, in consequence of the same irritation which the ligature has produced, accumulates upon the

* In Plate II. fig. 1, *f*, is represented a coagulum which, although of large size, has still retained this figure.

internal surface of the artery, and there forms a very distinct layer. (Pl. I. fig. 3, *f.*) It is this layer of unctuous substance which, assimulating in properties with the coagulable or plastic lymph already described, unites the surface of the coagulum with that of the artery at an early period: a circumstance which occurs so soon as this coagulum has become sufficiently large to fill the vessel. The precise time at which the coagulum comes into contact with the arterial parietes, varies considerably: I have occasionally observed it in young animals between the twentieth and thirtieth hour, but it usually takes place from the thirty-sixth or forty-eighth hour, and ocasionally at even a more remote date. Whenever it is accomplished adhesion between these parts is immediately established, but, similarly to that which takes place between the lips of the divided internal and middle membranes, it is very feeble in the first instance, but rapidly acquires a considerable degree of firmness. Until this time, the unctuous substance is poured directly upon the coagulum, but the exudation soon after ceases, at least, I have always found it impossible to detect any increase in the thickness of this layer, after it appeared reasonable to suppose, from its degree of consistency, that adhesion had existed for six or eight hours; and this is placed beyond doubt by the fact, that, reckoning from the period when the mass or size continues unaltered, its organization and structure are different, and become at this time changed in their appearance. (Pl. I. fig. 1, *d.*) To give a better notion of the character of the membranous layer which is formed upon the coagulum, it has been stripped from the superior and inferior portions.

It has been proved that the coagulum is formed and increases from the centre to the circumference, and that the enlargement of the arterial parietes is produced by the accumulation of unctuous matter upon their internal surface: in consequence, therefore, of this increment in opposite directions, that of the coagulum from the centre to the circumference, and that of the parietes of the vessel from the circumference to the centre, an union of the two must inevitably take place at one period or other. We have already

stated, that great differences are observed, as to the precise time when this is effected, depending upon a variety of circumstances to which the coagulum or parietes of the vessel, and frequently both these parts, are simultaneously liable, and the nature of which it is occasionally difficult to ascertain. This coincidence shews that the retardation of the union is more the result of some general defect of the organization, than of a local disease or accident: and such in reality is the fact; for it is ascertained that the general circumstances which most favour an early union of the coagulum with the artery, are youth, a plethoric and sanguineous temperament, and an inflammatory diathesis, which the individuals possess, either constitutionally, or from atmospheric influence: on the contrary, it is counteracted by old age, and a lymphatic constitution, which has been enfeebled or reduced by chronic disease.*

A knowledge of the local conditions is always easily acquired: they depend upon the healthy or morbid state of the artery, and the position of the ligature with reference to any large collateral branch: whichever state exists, so soon as the coagulum of blood has enlarged so as to fill the cavity of the artery, and it has united with the internal membrane by means of the flocculent matter which is intermediate to these two parts, new phenomena develope themselves, by which the magnitude of the coagulum is not increased so much as its organization.

It has been stated that the greatest addition to its size is made from the centre to the circumference: we shall now shew that the vital organic properties appear in its tissue, but that they take an opposite direction, i. e. pass from the circumference to the centre. Thus, the first molecule of the coagulum having been deposited by the blood in the centre of the vessel, so soon as it has formed an union with its parietes, they transmit to it the first vital motions; and the rapidity and vigour with which this is accomplished,

* See "Blood" in the admirable Lectures upon Comparative Physiology, by Professor Blainville.

are proportionate to the degree of vitality which the vessels themselves possess: in young individuals, when the membranes of the vessel are unchanged by the presence of any cartilaginous or osseous plates, this transmission of life to the coagulum, from the arterial parietes, is effected very rapidly; whilst, on the contrary, it either takes place very slowly or not at all, when these deposits are very numerous, and extend over the most considerable portion of the internal surface of the artery: similar results also occur, when the adhesion of the vessel with the cellular sheath has been extensively destroyed by any injudicious manipulations; for in this case the surgeon has deprived himself of one of the most valuable recourses towards securing the success of the operation.

When the artery, upon which the ligature has been applied, is placed under the favourable circumstances which have been pointed out, the first effects of the vital impulsion made upon the homogeneous mass of the coagulum, and the coagulable lymph by which it is united to the vessel, begin to be visible between the sixth and tenth hour after their union is completed; and are indicated by the surface of the coagulum and the substance connecting it with the internal membrane of the vessel, assuming a filamentous appearance,* which soon becomes areolar. This gradual change of coagulated blood into lamellated tissue extends through the successive layers of the entire substance of the coagulum; but, previously to the central portion having reached this degree of vital organization, red coloured striæ appear in those parts which are nearest to the artery. These seem to be absorbent vessels which slowly and imperceptibly take away the colorific principle of the blood, for the purpose of throwing it into the course of the circulation; and when this substance no longer exists, the striæ lose their colour, become solid and much more resisting than before, and ultimately terminate in forming the basis of the fibrous web, into which the sanguineous

* Pl. I. fig. 1. *d.* When a portion of the lymphatic substance which covers the coagulum is taken away, the most superficial layer of the latter is also removed.

coagulum is always changed. It is probable that each filament is formed of an obliterated vessel.

That I might be convinced of the vascularity of the red lines which have been described, I have frequently thrown fine injections into them, using every possible care, to avoid detaching the coagulum by the mode of injecting: * but I succeeded twice only in passing it from the vasa vasorum into their interior: in the other instances, the injection spread itself over the coagulum, and separated it from the artery. Should the latter circumstance not be considered to authorize the opinion which I have advanced, as to the nature of the red striæ which are found in the coagulum, it does not at least militate against it, any more than the impossibility of injecting the placental from the uterine vessels, does not overthrow the opinion which has been for some time received, respecting the double exhalation and absorption which reciprocate between the uterus and placenta.

Notwithstanding the first vessels appear upon the coagulum and the exuded substance by which it is united to the artery, before the end of the first week after the operation, and sometimes even prior to this, they do not penetrate its substance thoroughly, before the lapse of a much longer time, eight or ten weeks for instance: and it may be more or less in proportion to the thickness of the clot. The transformation of these vessels into lamellated, and subsequently, fibrous tissue is not completely effected until after a still further lapse of two or three weeks; this, as is well known, depending upon the age and constitution of the individual.

Whilst the phenomena which have been described are taking place, either in the lips of the division made by the ligature in the internal and middle membranes, or between these parts and the base of the coagulum, or the surface of the latter and the interior of the artery, others are developed in the parts constricted by the ligature: but they are of a much more simple

* To effect this, it is sufficient to place a ligature between the point tied, and that where the injection is passed, taking care to have between these two parts some collateral branches.

character, are less numerous than the former, and have also a more rapid progress. Three or four days after the application of a ligature, which has divided the internal and middle coats and includes the cellular tunic only, inflammation of this membrane takes place, if as we have supposed the thread be very small, and parts adjoining the ligature have not been injured by long and painful manipulations. In the first instance it will assume the adhesive character, the primary result of which will be to unite the superior and inferior ends of the artery which are placed in contact, in consequence of the pressure of the ligature. (Pl. I. fig. 4, *c.*) This union extends throughout the greater part of their circumference, but the size of the knot, and presence of one or both ends of the ligature, prevent it from being complete. In a short time the inflammation increases in intensity and extends above and below the ligature to a variable distance: but I have never observed it pass to a greater distance than two or three lines in each direction, beyond that portion of the vessel which has been denuded or insulated from its sheath. Five or six days after the operation, the inflammatory action which is seated in the parts included by the ligature, terminates in suppuration. The effect which is first observed, is the destruction of the albuminous tissue uniting the two ends of the artery, (Pl. I. fig. 4, *c.*) This is succeeded by the detachment of that portion of the cellular membrane which is included and destroyed by the ligature, and by the escape of the silk. If the inflammation of this part be not extremely violent, that which has been described as extending to the distance of some lines upon the artery, maintains a lower degree, and does not pass into suppuration: by this, the resisting power of the cellular membrane is increased and not diminished, because whenever inflammatory action does not terminate in the suppurative process, a thickening of the tissues is produced, and a greater degree of firmness acquired.

During the period that the inflammation is extending upon the surface of the artery, it also penetrates to the centre of each of its extremities; but, as

in this point it meets with the inflammation which has already taken place in the divided lips of the internal and middle membranes, its intensity is here increased, and suppuration ensues: and thus, the adhesion (Pl. I. fig. 5, *c*, and fig. 3, *c*,) uniting these parts to each other and to the base of the coagulum, is always destroyed. It hence appears, that the means which nature primarily employs for obliterating the vessel, entirely disappear; *and at this time the coagulum and its union with the internal membrane offer the only preservative against consecutive hæmorrhages.* (Pl. I. fig. 1, *c*, *d*; *ib.* fig. 7, *e*, *c*; *ib.* fig. 10, *f*, *e*.) The positive necessity, therefore, of the presence of a coagulum of considerable size to render the operation successful is evident, whether it shall have been performed upon an artery of large or middle size, as for example, the crural and brachial.* I have asserted that the union of the internal membrane with the coagulum is more intimate in the small than large vessels, (Pl. I. fig. 8, *d*,) because they enjoy greater vital powers. A similar remark has been advanced when making the comparison between the arteries of old, and those of young men: the former corresponding in their result with the large trunks, and the latter with the smaller vessels. The favourable chances of the operation are then all on the side of youth. Should a coagulum not be formed, which is the case when the ligature has been placed too near a collateral branch of rather a large size, hæmorrhage will inevitably follow the rupture, or rather the destruction of the cellular membrane, which the suppuration occasions. The same accident occurs if, from any cause, the external inflammation of the vessel becomes very intense, and is propagated through the tunics to the coagulum: but, in this case, the hæmorrhage happens rather later, because some time must elapse before the coagulum can be destroyed. When speaking of broad ligatures, we shall trace and describe the disappearance of this body in consequence of suppuration.

* Mr. Guthrie says, "My observations have *not* led me to believe *that a coagulum is absolutely necessary* to the permanent closure of the artery, although it certainly assists in maintaining it."

Of broad and flat Ligatures. When, instead of a round and small ligature, one that is broad and flat is applied upon an artery, (such, for instance, as are formed by uniting four or five threads until it has about two lines in breadth,) the appearance and succession of phenomena which have been described, become modified in a singular manner; and, as every condition of the operation (with the exception of the form and size of the ligature) correspond, it results that all the marked differences must be strictly attributed to this cause, inasmuch as it is the only circumstance which has varied.

It is unnecessary to recapitulate the general precautions which are indispensably requisite in laying bare and insulating the artery, or respecting the mode of tightening the ligature, as these points have been already considered and are always similar, whatever be the kind which is to be applied.

When an artery is tied by a broad ligature, its opposite parietes are forcibly approximated: after they have been placed in contact, if the application of the power is further continued, the internal and middle membranes are ruptured by a species of triturating or grinding operation, for an extent equal to the breadth of the ligature: and as the section which is made is irregular, it consequently happens, that processes or elongations of these tissues are always left in that portion of the cellular membrane which the ligature includes and constricts.

These shreds or processes prevent that slight folding or retraction from above and below, and that inclination of the divided lips of the internal and middle membranes towards each other, which have been described as taking place when a small ligature is used (Pl. I. fig. 5; *ib.* fig. 1.); and hence not being maintained in contact at the point of section, but on their internal surface only,* they are placed in the outset, under less favourable

* Pl. I. fig. 3. In examining the opened artery, *a*, the ligature, it will be seen that the divided lips of the wound made in the internal and middle membranes are not turned to the centre of the vessel, as is observed in fig. 5, and fig. 1.

circumstances for their early agglutination. The coagulable lymph which exudes, is effused externally between the surface of the lips and the cellular tunic, instead of being poured out between the lips and the interior of the artery, where it fixes the first rudiments of the coagulum, when a small ligature is used. As that which ought to have been internal thus becomes external, the extremities of the artery are separated from each other for a distance equal to the breadth of the ligature, the adhesion or flocculent union which, under the application of a narrow ligature, is effected between these two portions of the vessel, (Pl. I. fig. 4, *c.*) is by this intervention rendered altogether impracticable (Pl. I. fig. 2, *b.*): and the ligature consequently continues exposed throughout the entire circumference of the vessel; a circumstance which, in conjunction with its magnitude, materially contributes to increase the suppurative inflammation which must necessarily supervene.

It has been already stated, that the position of the lips of the divided internal membranes is such, in a vessel tied with a broad ligature, that the plastic lymph which is effused, is distributed externally upon the cellular membrane: this fact is proved in the third figure of the first plate. For no appearance indicative of the presence of this plastic lymph, which ought to cover the edges of the section of the internal membranes of the artery, can be found either upon the vessel or the ligature *a*: whilst, on the contrary, in the same artery, ligature *c*, this substance is found as abundantly as in figure 5 and 1, because in this preparation, as in those which have been described, the ligature was made of a single thread. The deduction, therefore, which must be drawn, is, that the difference in the results can only be attributed to a difference in the size of the ligatures employed, as the comparative experiments were performed upon similar arteries, and, in one instance, upon the same vessel.

In consequence of the plastic lymph being poured out on the exterior of the cavity of the internal membranes of the artery, the opposite sides of this membrane adhere at their point of contact, merely by the quantity of

unctuous matter which is secreted: and this adhesive process takes place also at a much later period than when a small ligature has been employed.

The same is also true respecting the union of the coagulum with the lips of the small wound: for the filaments of coagulable lymph, (Pl. I. fig. 5, *c*; *ib.* fig. 3, *d*, *d*,) which are so well calculated for fixing the primary molecules to the apex of the arterial cavity are absent: as this point of support is wanting, the coagulum only begins to appear about twelve or fifteen hours after the operation, and continues to increase very slowly; this is probably attributable to its great mobility. In fact, the coagulum *b*, of figure 3, is loose throughout, whilst that of figure 5, upon which the operation was performed at the same time, is already attached by its base to the filamentous tissue of the new formation *c*. It is, therefore, apparent that the first phenomena which follow the application of a broad and flat ligature upon an artery,—the relative situations of the divided lips of the internal and middle membranes, the exudation of plastic lymph by which they ought to be temporarily united, and lastly, the appearance and growth of the coagulum, are retarded by its employment. As these phenomena are dependent upon each other, it is only necessary that one circumstance be changed to cause a variation in the whole of the remainder. And thus, in the present instance, by the irregularity in the relative position of the lips of the section of the arterial parietes, the whole of the consequences become modified.*

If, in the case described, the phenomena which first succeed the operation make very slow progress, great difference is observed in the rapidity of such as ought to take place more tardily, by which the operations which nature has performed for producing an obliteration of the vessel, are destroyed: for in consequence of the size of the foreign body which is left in the wound, the inflammation is more rapid and much more violent; and, instead of the suppuration being limited to the parts which are in immediate contact with

* If the state of the divided edges of the parietes of the artery, fig. 3, ligature *a*, be compared with the same parts in fig 5, an exact idea will be obtained of what is meant.

the thread, as when a small ligature is applied, it always extends to a distance of eight or ten lines, at least, and sometimes more, upon each extremity: moreover, this inflammation will have a much longer duration, because the included tissues are compressed for a greater extent, and divided more slowly than when the pressure is confined to a much more limited surface: it is, therefore, probable that the greater part of the adhesion of the coagulum to the parietes of the vessel will be destroyed by a suppurative inflammation which passes from the exterior to the interior of the vessel. Under these circumstances, the base of the coagulum is loosened and rounded, and that portion of its surface which is detached from the artery is smooth and covered by a layer of pus. (Pl. I. fig. 10, *d.*) When this coagulum is compared with that of the opposite end of the same figure, *e*, in which inflammation has not occurred, an accurate notion will be obtained of the primary changes which this process induces: the former is small, loose in the artery, and destroyed by suppuration from its base to the apex; the latter, on the contrary, possesses a very regular conical figure: its entire surface adheres to the internal parietes of the vessel, and the edges of the truncated base are firmly united to the lips of the division made in the internal and middle tunics (Pl. I. fig. 10, *c.*): the same arrangement is also very strongly marked in figure 7, *e*.

From what has been explained, it will be inferred, that if the distance which is found between the ligature and a considerable collateral branch, as we have supposed, be similar in both modes of operation, the probability of success is altogether in favour of small ligatures, because by their use, those suppurations which destroy the coagulum, to a greater or less extent, are altogether avoided: for it is easy to understand, that if suppuration has destroyed the coagulum to the extent of seven or eight lines, the size of the whole not exceeding ten or twelve lines, the remaining portion will be insufficient to withstand the impulsion of the blood. In this instance, hæmorrhage is more sure to supervene, in proportion as the performance of

the operation is speedily succeeded by the suppurative process. If no general circumstance oppose the adhesion of the coagulum with the artery, union is usually so strong in twelve or fifteen days, that the most feeble remains of this body are capable of preventing hæmorrhage.

But should any peculiarities, as the advanced age of the patient, an altered state of the arterial tunics, or an undue insulation of the vessel by the surgeon, have retarded the developement of the adhesion which has been described, hæmorrhage then becomes inevitable. When inflammation and suppuration have almost entirely destroyed the original coagulum, the hæmorrhage may be prevented by the formation of a new coagulum, or rather by an increase of the remains of the former. This growth is facilitated by the slight degree of inflammation which is invariably found at the limits of one of greater degree; and produces a more copious exhalation of unctuous matter, precisely similar to what has been observed to take place, at the two ends of an artery upon which a single ligature has been applied. It may easily be supposed that for effecting this, it is indispensable that the distance found between the part where the secondary developement of the coagulum takes place and the origin of a large collateral branch, is as great as nature requires: for, unless this is the case, every effort which she can make will be ineffectual. If, for example, the ligature is placed upon the middle portion of the femoral or towards the superior portion of the carotid artery, though the coagulum were destroyed to the extent of an inch or an inch and a half, the danger of hæmorrhage is not imminent: but should its situation be one or two inches below the origin of the femoral profunda, or an equal distance beyond the origin of the carotid artery, the coagulum, being incapable of increase in consequence of the great mobility and power of the column of blood which is incessantly beating upon it, is partially or entirely detached from the parietes of the vessel, and ultimately is rapidly removed by the same power, which has prevented the secondary developement. This condition is immediately succeeded by hæmorrhage.

After what has been advanced, the great importance of the precept which practitioners have laid down, will, I think, be admitted, viz., that when it is necessary to tie an artery, all the collateral vessels which are of a certain size, must be avoided as much as possible, especially if they are situated between the heart and the ligature. The proximity of the collateral vessels which are situated between the ligature and capillaries, although in some instances of much larger size than those already described, is not nearly so pregnant with danger, because, however rapidly the blood may be carried from the superior to the inferior end, it never acquires an equally impulsive power in the latter as in the former: there is consequently less apprehension of any displacements of the coagulum, and of secondary hæmorrhage.

We think, therefore, that in accordance with the mode in which hæmorrhages have been proved to take place—consequent upon the tying of an artery, there can be no hesitation in selecting the small in preference to the large ligature: for it has been shewn, that hæmorrhage invariably results from suppurative inflammation seated in the extremities of the artery; and also that this inflammation is particularly favoured by the presence of a large body in the bottom of the wound: from the whole, then, this conclusion must be drawn, that, all other circumstances being equal, the use of a small ligature, is preferable to that of a broad ligature, from the advantages which it secures.*

* It appears highly improbable, that a broad flat ligature should make such a wound in the internal and middle coats of an artery, as is most favourable to adhesion: because it is scarcely possible to tie it smoothly around the artery, which is very likely to be thrown into folds, or to be puckered by it, and consequently, to leave an irregular, bruised wound, made in its middle and internal coats. And even if it should make a proper wound, yet, by covering a considerable space of the external surface of the artery, it may destroy the very vessels which pass on it in their way to the cut surfaces of the internal and middle coats, and thereby render them incapable of inflaming.

* * * But admitting that such a ligature makes a proper wound, and that the wound unites, still it may cover that part of the external coat which is directly over the newly united part: and consequently, as soon as it has occasioned ulceration through the external coat, it will produce the same effect on the newly united parts, and of course secondary hæmorrhage." Jones on Hæmorrhage, p. 168. (Trs.)

Should any doubts remain in the reader's mind, it is hoped that they will be entirely removed by the observations which have now to be brought forward.

Of Ligatures, with a foreign body interposed between the artery and thread. *Scarpa* first suggested the interposition of a foreign body, of a certain size, between the ligature and vessel which it was intended to obliterate, for the purpose of preventing any division of the internal and middle tunics by the ligature, and the too speedy section of the entire artery: the principle is similar to that which is exemplified in the use of the *presse-arteres*, but is modified and rendered somewhat less disastrous in its consequences. The object of this method, as well as that of the *presse-arteres*, was to produce an obliteration of the vessel by flattening it, and the mere approximation of its opposite parietes, without producing the slightest physical change in its tunics. *Scarpa*, in common with the surgeons who preceded him and had proposed the use of these instruments, attached great importance to the latter consideration, and thought that the province of art could not extend further in effecting the ultimate closure of arteries, than by completely suspending the passage of the blood through their cavity, without producing any injury in their tunics. (Appendix I.)

It has been before stated, when treating upon large and flat ligatures, that their use was injurious in the first place, in consequence of the effects which they produced upon the parietes themselves, of the vessels, the internal and middle membranes being divided by a force of a contusive nature, a circumstance which invariably retarded their agglutination: and in the second, because the consecutive inflammation was always more formidable under the use of a broad than of a small ligature. If, as we have shewn, these facts are true, it must naturally be concluded that, (all other things being equal, a supposition which must always be made,) the larger the foreign bodies are, which are retained in the wound, the greater is the probability of a considerable and extensive inflammation, and consequently,

that the expectation of a successful termination of the operation is proportionately diminished: it must hence be admitted, that the plans which have been proposed of producing a flattening of the artery, are more liable to produce hæmorrhage, than the application of constriction formed by a single thread.*

In adopting *Scarpa's* method, that is to say, in placing between the parietes of the artery and the ligature which is formed of four or five threads, a cylinder of linen, two lines in breadth, and four or six in length, when the ligature is moderately tightened, the vessel is obliterated by the mere contact of its opposite parietes: but if under the same circumstances, the ligature is tightly applied, the internal and middle membranes are divided throughout the entire circumference of the artery which is unprotected by the cylinder—a division which is more irregular and uneven than that produced by the use of broad ligatures only: by this, the artery is placed in a state for procuring an early closure still less favourable than when a foreign body is not interposed between the vessel and a large ligature, in as much as it has been shewn that the greater degree of irregularity and contusion which are occasioned by the division of the tunics, the more slowly is adhesion effected. In the second place, it has been demonstrated with equal clearness, that the liability to those accidents which are most to be dreaded from the operation—inflammation and suppuration, is always in direct ratio to the size of the foreign bodies which are left in the wound: it must, therefore, be concluded, that *Scarpa's* method is more detrimental

* In expressing a contrary opinion, Scarpa says, "By the ligature of the great arteries, as a radical method of cure of aneurism, I do not mean a noose, with which the artery is constricted circularly, but I wish to be understood to speak of a pressure made by a ligature of convenient breadth upon the artery, by means of which its two opposite sides are brought into mutual contact, without the noose resting or pressing strongly upon the sides of the artery, which is flattened rather than constricted circularly. And it is in this manner, that the surgeon avoids the danger of the rupture of the artery, and of a secondary hæmorrhage, and that he is assured of obtaining the approximation of the two compressed sides of the artery, as if they were two smooth planes placed over the other, and that they contract an adhesion to each other." (Trs.)

than the use of a large ligature alone. The talented Italian Professor, however, expressly recommends, in his last memoir on this subject, that the ligature be only tightened to such an extent as will approximate and maintain the opposite parietes of the artery in contact with each other, so as to prevent any transmission of the blood beyond this part, without any division or bruising, that the action of their vital powers may be disturbed or impeded as little as possible.*

We shall now proceed to examine whether or not this mode of operation ought to be preferred to the use of round and small ligatures; and whatever may be advanced upon this subject, must be considered equally applicable to the use of the *presse-artere*, because the principles of both are the same: but, were we compelled to adopt one or the other of these plans, *Scarpa's* method would receive the preference, because the size of the foreign substance which is left in the wound is less than that of a *presse-artere;* and in the second place, because the solid and unyielding nature of the instrument occasions much more serious difficulties than the apparatus employed by *Scarpa*.

The phenomena which directly succeed the flattening of an artery by the contact of its parietes; (no physical lesion of membranes having occurred,) are simple and few. The figure of the cavity of the vessel is rendered

* After describing the previous steps of the operation he proceeds, " The surgeon will then pass behind the denuded raised artery a large-eyed, crooked needle, with a blunt point, carrying in the eye near to the point, two waxed ligatures, each composed of six threads. After this he will withdraw the fore-finger of his left hand, on the point of which he kept the femoral artery raised from the bottom of the wound, and will proceed to the ligature of the artery. He will stretch the two extremities of the tapes in order to place them near each other, he will then make with each a simple knot, and before tightening it on the artery, he will place between it and the knot a small cylinder of linen rolled up, six lines in length and three in breadth, over which cylinder he will tighten both ligatures with a simple knot, and with such a *degree of force as he thinks necessary to bring the opposite sides of the femoral artery into complete and firm contact, not forgetting, however, that he compresses a portion of living solid.* Over the first knot he will make a second, likewise a simple one. In making the simple knot, the surgeon is enabled to calculate the force which he employs in constricting the artery which he cannot so well ascertain when he employs the double or surgeon's knot as it is called." Scarpa, p. 281. (Trs.)

conical above and below: the blood penetrates on both sides as far as the apices of these flattened cones, but its coagulation only proceeds very slowly. (The same order in the mode of description will be followed in this, as in every former instance, those changes only being described which take place between the point of obliteration and the heart; those which occur between this point and the capillaries being similar, but more indistinct.) Instead of observing the elementary rudiments of the coagulum between the sixth and tenth hour after the operation, as when the internal and middle tunics have been divided by a small ligature, in general I have seldom noticed them until after the twelfth hour, notwithstanding the extremely pointed figure of the cavity of the vessel must operate very favourably in facilitating the coagulation of the blood, when compared with the somewhat perpendicular closure, which arrests the circulation of this fluid, when a small ligature has been applied. In the former case, the impulsive force of the blood must be materially diminished, whilst in the latter it is maintained nearly perfect, its power being very little modified. Some cause, therefore, which is important for the formation of coagulum is wanting, since, notwithstanding the favourable disposition of the arterial cavity, the period when this begins to appear, is retarded; this consists in the absence of plastic lymph which is abundantly supplied by the edges of the wound, when it has been made in the parietes of the vessel by small ligatures: for, unless the internal and middle tunics are divided, the only substance which the artery pours out to assist in forming the coagulum, is the unctuous lymph which exudes from the internal membrane; the plastic matter, on the contrary, which is secreted from the wound of the membranes, in the first place answering the purpose of uniting the lips of the wound, and then expanding itself in the vessel, there forms a small tubercle which becomes the centre of the rudimentary coagulum. It is readily perceived, that as this nucleus is wanting when the artery is merely flattened, the difficulty of producing the coagulation of the blood must be increased: and such is the fact. The

coagulum can only appear when there is a point for its attachment; and if the tubercle of plastic matter is not formed, the unctuous lymph of the internal membrane is the only means of furnishing it: but, as the union of the latter substance with the apex of the vessel is much slower than that of the former, the coagulum also, under these circumstances, must appear at a later period.*

When the coagulum first appears, instead of being attached to the artery by a broad base, as is seen, (Pl. I. fig. 1, *f.*) its only connexion is formed by a small point (nearly similar to that exhibited in Pl. I. fig. 3, *b.*); it is, therefore, very mobile for a considerable length of time, and its primitive increase is thus materially impeded: but after it has become sufficiently large to fill the arterial cavity, the developement of its consistency and organization, run through the same course as in the preceding cases. The whole difference, therefore, is attributable to the smaller and more feeble union which it contracts with the bottom of the vessel.

The flattened portion of the artery, which varies in extent according to the length of the compressing plate of the instrument applied, or the cylinder, if this has been used, suffers so great a degree of pressure from these contrivances, the vitality of its tunics is almost entirely suspended; and thus, the changes which result in the interior of this portion of the vessel, may be supposed to be almost reduced to the lowest degree (zero or O): for when the artery is opened two, three, or even four days after the operation, very few traces of unctuous matter can be perceived; whilst, if the passage of the arterial blood be suspended, by applying upon the vessel two ligatures, at any distance from each other, and the interior of the vessel be examined, only twelve to fifteen hours after, this substance has been formed in consider-

* From what has been said, it must not be supposed that when the substances which have been described, are wanting, no coagulum whatever is formed: it is always produced, but much more slowly.

able quantity.* The different results obtained under these two circumstances are distinctly caused by the different states of the arterial parietes—which, in the former case, are struck with death, (if the expression may be allowed,) whilst in the latter their vitality is maintained. (Appendix K.)

It may be deduced, therefore, from what has been advanced, that, in the first place, by the plan of flattening the artery, the formation and adhesion of the coagulum with the arterial parietes take place more slowly than when a small and round ligature is used; and secondly, that the artery suffers an entire destruction to an extent equal to the length of the compressing instrument which is applied: whilst by the other method, a linear portion only is destroyed. It remains to be examined, whether the advantages of the consecutive phenomena compensate for the inconveniences which have been described.

It has already been previously stated and proved, that the effect of every application of a ligature upon an artery, is to produce a suppurative inflammation which destroys the cellular tunic included by the ligature, together with the first adhesions formed by the coagulum to the cul de sac of the artery: and also, that all other circumstances being equal, the degree of inflammation is always proportionate to the size of the foreign body which is left in the middle of the living tissues. If these facts are correct, *Scarpa's* method ought to possess fewer advantages than those obtained from the use of broad ligatures alone; and the application of the *presse-artere*, in consequence of its size, should entail greater inconveniences than every other mode of operation, and such is the case. Whilst the inflammation, which arises from the application of a small ligature, does not extend to a greater distance upon the two ends of the vessel than a few lines, that which is occasioned by the presence of a cylinder, five or six lines in length, is much more severe. It not only extends further on the surface, but also to a greater

* Pl. I. fig. 3, *f*. A considerable quantity of this unctuous matter existed, between the two ligatures of the carotid *b*, Pl. II. fig. 1. But it was removed by maceration for thirty hours in water.

depth; and invariably affects the three tunics and the coagulum itself, so as to occasion the partial destruction of the latter: this circumstance, agreeably with the statements which have been already made, always precedes the secondary hæmorrhages: and the violence of this inflammation, which is primarily produced by the presence of a large foreign body, is maintained and increased by the necessity of dividing the three membranes of the artery, which, as is very well known, is accomplished with greater difficulty than when the cellular membrane alone is constricted by a single thread. (Appendix L.)

Under these circumstances, this section of the vessels is effected with so much slowness, that the various periods of its progress are easily traced when attentively watched. When four or five days have elapsed after the operation, and the parts which touch the apparatus have taken on the suppurative process, the fibrous membrane as yet is merely softened: but two or three days afterwards, the fibres are thoroughly divided by intersections in such a manner, as to give to it a dentated appearance,* and during the time that this division is taking place, the peculiar tissue of the middle membrane entirely disappears. The destruction of this tunic continually proceeds for an extent of six or ten lines above and below,† but it occasionally

* Pl. II. fig. 1, *g*. That the figures might not be unnecessarily multiplied this has been used as shewing accurately what I have described, although the ligature used was formed of two threads only: but the knot having followed the superior end during its retraction, induced a considerable degree of inflammation in this part, and, in consequence, a portion of the internal and middle membranes were destroyed by suppuration.

† Pl. I. fig. 9, *b*, indicates the situation where the ligature was placed. From this point as far as the ends of the artery, it is easily perceived that the internal and middle membranes are wanting: they are entirely destroyed from *b* to *g* and *h*: but from the two latter points to *c* and *d*, some remains are seen upon the two coagula. This figure shews that the membranes are destroyed from the exterior to the interior, and in addition to this, that after suppuration has extended its ravages upon the internal membrane, it then affects the coagulum itself, which therefore is invariably destroyed after the membranes: and it is clear that if in this animal the distance had not been considerable, between the point where the ligature *b* was applied, and the origin of a large collateral branch, hæmorrhage would have resulted: the same is true also in that represented in Pl. II. figure 2, in which the destruction of the middle and internal membrane, and of the coagulum extends still further, because a much longer period elapsed from the performance of the operation.

extends further upon one extremity of the vessel than the other, if the cylinder is unevenly applied.

It must here be remarked, that the position of the ligature on the end of the vessel, however small it be, greatly influences the success of the operation: for instance in figure 7, the presence of a single thread upon the inferior end of the artery has been capable of exciting a suppurative inflammation which has destroyed a portion of the arterial parietes, and almost the whole of the coagulum. In figure 10, the ligature continued fixed upon the superior extremity: this is also the point which the suppuration has affected: and lastly, figure 12, the ligature which was formed of four threads, remained for ten days after the operation attached to its superior end by cellular filaments, which were sufficiently strong to have retained it perhaps four or five days longer. But, in this subject, who was probably little disposed to inflammatory action, no extensive suppurative inflammation supervened which was capable of destroying a considerable portion of the artery and coagulum at once, examples of which have been given, but rather a species of corrosive inflammation which wasted both these parts at the same time: and it is easily proved when the same artery is examined after being laid open, figure 13, that had this erosion continued, hæmorrhage must have inevitably occurred. This fact shews the necessity of attending to the recommendation which has been given by every author, that the ligatures should be taken away so soon as they can be removed, without requiring the exertion of any degree of violence. This precept ought to be especially regarded, when the foreign body continues attached to the extremity of that portion of the vessel which is nearest to the heart.

Hence, according to *Scarpa's* method, and more especially, under the use of a *presse-artere*, a very considerable extent of the vessel operated upon is destroyed by the mere agency of the instrument or apparatus applied: and in addition to this, the extensive suppuration which always supervenes, terminates in a much greater destruction of the part than when the ligature is formed of a small body. The deductions from these facts are; that hæmorrhages must be

more frequent after using large than small ligatures: that this terrible misfortune is almost invariably produced when the space which intervenes between the point of obliteration and the origin of a large collateral branch is insufficient to allow the formation of a coagulum: that whether this space is at first wanting, from having placed the ligature too near the origin of an adjoining branch; or that it is so much reduced below the necessary size by suppuration, that the coagulum is incapable of resisting the impulsion of the blood, the consequences are the same. Further, under the latter circumstances, at the same time that suppuration destroys the membranes of the artery, and the substance of the coagulum, it is propagated to some distance upon the cellular tunic, and this occasionally insulates it together with the parts by which it is surrounded, to a distance of ten or fifteen lines, so as to prevent the remains of the coagulum from maintaining such an adhesion to the internal membrane as would be sufficiently strong to resist the impulsion of the blood: whilst so long as the vessel operated upon maintains all its connexions, and consequently enjoys perfect vitality, its union with the coagulum is so perfect, that the smallest portion of its remains is frequently sufficient to prevent hæmorrhage.*

To prevent the accidents which have been mentioned, *Scarpa* actually recommends the ligature and cylinder to be taken away three or four days after they have been applied upon the vessel. This is a very considerable improvement upon his mode of operation. The consequent inflammation and suppuration are undoubtedly less severe when the foreign bodies are taken away at an early period after the operation, than if they are left to be expelled by the efforts of nature, but this circumstance by no means proves that *Scarpa's* method is superior to that of Dr. *Jones's*: for at the moment even when the ligature is withdrawn, the inflammation is much more active, within the wound than when a single thread only is used.† And, moreover,

* An example of this is given, PLATE I. fig. 12.

† Whenever some particular circumstance, independently of the ligature does not increase it, as is instanced in the animal from which the preparation given in PL. I. fig. 7, was taken.

the motions and unavoidable displacements which the extremities of the artery must suffer during this second operation, which is always as painful as the first, must also, when the vessel is deeply situated, tend to increase it: and it would be by no means impossible when these manipulations are performed, but a short time after the suspension of the circulation of the blood in the artery, and before the coagulum has become firmly adherent to its parietes, that immediate hæmorrhage should be produced, especially in elderly individuals, in whom the arterial tunics are very friable. (Appendix M.)

In consequence of what has been said, I think that the use of small must generally * be preferred to that of large ligatures, however their mode of application may be modified. Though I am fully aware, that very celebrated surgeons, as *Palletat*, *Monoir*, and many others, report a successful result from the practice of *Scarpa's* method of operation, whilst others, as M. *Roux*, daily derive the same advantages, without even adopting the modifications which he recommends; I am convinced, notwithstanding, that these practitioners would have met with more certain success, had the small ligature been applied.† (Appendix N.)

* I say, "generally;" because it will soon be shewn, that when the arterial parietes are diseased, the broad ligature, or even Scarpa's apparatus are preferable to the small ligature.

† "It was discovered by the celebrated Desault, that a round ligature drawn tight upon an artery made a clean cut of its internal coat, and the experiments of Jones, devised and executed with equal felicity, have established that the obliteration of an artery tied with a round ligature, is *only* the cicatrization of this cut. To ascertain, with precision, the effects of ligatures of various sizes, both flat and round, I have repeatedly examined the appearances left upon the cuticular coat of the artery after applying them, and the following is a report of such experiments upon the carotid, iliac, and femoral arteries of the human subject.

Broad tape	No distinct impression but a general longitudinal puckering of the internal coat, especially opposite the knot.
Narrower ditto tape	
Narrow tape	The same with partial laceration.
Narrower ditto tape	Cuts with a fretted edge, or partly cuts and partly tears.
Flat bobbin	The same.
Large round bobbin	Cuts cleaner.
Twist	Clean and narrow incision.
Twine	
A round ligature including a cylinder of linen	Faint but distinct incision.
Ditto including a cylinder of quill, wood, or other firm substance	Deep but some what partial incision."

Travers. Med. Ch. Trans. vol. iv. p. 437. (Trs.)

Of torsion of Arteries. It has lately been proposed to arrest the circulation of the blood in arteries, by performing upon them the operation of torsion; thus to avoid the necessity of leaving any foreign body, either in the wound or upon the vessel. We shall not enter into any considerations respecting the question, who is to be regarded as the discoverer of this mode, or remark upon the eulogiums which it has of late received: they who are personally interested in the inquiry must claim, and the public determine, what share of merit is due to them; at present it will be merely stated that this operation was proposed by M. M. *Amussat*, *Velpeau*, and *Thiorry*, almost at the same time, and that each of these surgeons adopts a peculiar plan. The two former have recommended its use in those hæmorrhages which are consequent upon the great operations or the wound of an artery: M. *Thiorry*, however, proposes that it should be applied to the treatment of aneurisms, i. e. to arteries which maintain their continuity and have been exposed by an operation of the surgeon. In these cases, he insinuates a solid instrument under the body of the vessel, with which he twists the artery in such manner as to produce an effect which corresponds exactly with that obtained from the pad of a tourniquet which encircles an extremity, when it is compressed before the performance of an amputation. Should the vessel be wounded, or cut through, as occurs during amputation, M. *Thiorry* seizes it with Patin's forceps, (selecting them of such size as is proportionate with that of the artery,) and performs the operation of torsion by giving to them a complete rotary motion, which is performed five or six times successively, when the vessel is small, and ten or twelve times when of a large size.

M. Velpeau uses a pair of grooved, or even common dissecting forceps: he lays hold of the extremity of the arterial tube, and carefully separating it from the surrounding parts, applies another pair to the highest point of its insulated portion, for the purpose of fixing it firmly, and at the same time twists the denuded portion of the artery with the first forceps from three to eight times in succession, according to the size of the vessel.

M. *Amussat*, employs in the operation, two pairs of forceps of very complicated construction, each furnished with a contrivance by which he can keep them firmly closed. With one, he seizes the vessel, and withdraws it from the wound for the purpose of thoroughly separating it from the surrounding veins and nerves; when this is done, he applies the second forceps, which have round even arms, upon the artery immediately above the extremity of the first forceps, and by making strong pressure upon the rounded arms he thus divides the internal and middle membranes; and when it is probable that he has effectually succeeded in this, he slides the second pair of forceps along the insulated portion of the artery, until he reaches that part of the vessel, which has not been denuded, and thus reflects or pushes the two internal tunics before the instrument. Having carried the second pair of forceps as far as this point, M. *Amussat* then maintains their firm and steady application, at a distance of at least four or six lines, from the first pair which have been already fixed upon the extremity of the artery—with the latter, he then torts the cellular tunic (the only membrane which has resisted the bruising or scraping action of the rounded forceps,) five or six times in succession.

By these various plans of twisting arteries, any discharge of blood from the vessel is immediately arrested, by the plug formed of the ruptured internal and middle tunics, (Pl. II. fig. 9, *a*,) when it is performed according to M. M. *Velpeau's* and *Thiorry's* plan, or by an inversion in the artery of the same parts, for a length of three or four lines, (Pl. II. fig. 12,) when *Amussat's* mode is adopted. Under both circumstances, the cellular membrane, the only one which is in reality twisted, forms below the plug or the membranous inversion, a kind of cul de sac, (Pl. II. fig. 9, *b*: *ib.* fig. 12, *e*,) which, by slightly pressing against the obstacle which resists the escape of the blood, is capable, when necessary, of preventing its discharge; should it happen that by insinuating itself through the debris or portions of the internal and middle tunics, it passes beyond the impediment which these fragments

oppose to its progress, or, if after torsion has been made according to M. *Amussat's* mode, a portion of the sanguineous column passes into the canal which is formed by the inverted membranes. (Pl. II. fig. 12, *a.*) In this, as in the former instance the flow of blood from the artery would be impeded by the portion of cellular membrane which forms the cul de sac described. (Pl. II. fig. 12, *c*: *ib.* fig. 9, *b.*)

It thus appears, that, when torsion has been well executed, hæmorrhages are successfully and with certainty arrested: but this is not the true point of view in which the operation ought to be regarded: for if the only object in view were that of producing an immediate stoppage of the discharge, nothing could better fulfil this indication than the judicious application of a ligature of any kind, either large or small. The real question to be determined, is, whether consecutive hæmorrhages are less frequent after the use of torsion, or the application of ligatures of the most advantageous nature and form. Those surgeons who have advocated its use, have most strongly insisted upon the correctness of this opinion. M. *Amussat*, especially, thinks that torsion possesses great advantages over the ligature: because, he says, when it is used no foreign substance is left in the wound: the consequence is, that the consecutive inflammation and suppuration amount almost to nothing, and, therefore, the cicatrization of the parts takes place much more rapidly than when a ligature is applied: unfortunately, these favourable consequences of the torsion of arteries, have not been always observed. Several surgeons assert that they have noticed that inflammation and suppuration extend and continue a much greater length of time when torsion has been used, after the performance of an amputation, than in cases nearly similar when the ligature was applied:* others mention the occurrence of hæmorrhages, almost immediately after the operation,† and thus the anticipations which this proposal appeared to induce are in reality destroyed.

* See Delpech's Memoir in la Revue Medicalè. Oct. 1831. † See Journal Hebdomedaire, vol. v. &c.

M. *Velpeau*, however, who, as we have stated, was one of the first to adopt its use, and the extent of whose talents every one appreciates, states that torsion is not applicable to every case, and that in none does it possess a real advantage over the ligature. I have never employed this hæmostatic remedy in the human subject: but I have performed numerous experiments upon dogs and rabbits for the purpose of comparing it with the ligature, and have constantly found that when torsion is employed, instead of the ligature, upon the large, or at least upon vessels of medium size, the inflammatory action and suppurative process have been more violent and of longer continuance than when an artery of similar dimensions had been tied: and the reason, I think, appears evident.

In the first place, the manual operation of torsion is more difficult and painful than that of applying a ligature. Indeed, if it is wished to practice torsion upon the continuity of an artery, the same precautions must be used in laying it bare, which have been exhibited when describing the general rules for the application of the ligature, with the exception, that, in the latter case, so soon as the vessel is exposed, it is only further necessary to separate it for a short distance to apply the thread, and the operation is concluded. But, on the contrary, if it is intended to perform torsion, the artery having been exposed, several painful and tedious manipulations have still to be executed—the section of the artery with the bistoury, and the insulation and torsion of its divided extremities: it is proper to say, however, that no one has insisted upon the use of torsion in those cases wherein the continuity of the vessel remains undisturbed.

We shall now examine whether this operation, or that of applying a ligature after the amputation of the extremities, or the extirpation of tumours, is performed with the greatest ease: in either method the vessel must be seized and insulated. When the ligature is to be applied, the separation is made sufficiently extensive by merely exercising upon the artery a slight degree of traction, but when torsion is employed, a greater degree of traction

is required than that which the ligature demands, so as to make the vessel project five or six lines, at least, beyond the fleshy parts; and, as this attempt invariably draws the veins and nerves by which it is accompanied along with the artery, it becomes necessary to separate and turn them back towards the superior parts, for the sole purpose of twisting the artery, a precaution which the ligature does not always require, and which it is unnecessary, in any case, to carry to that extent which torsion demands.

After the separation has been effected, torsion still remains to be performed.

From what has been said, the operation of torsion is proved to be longer, as well as more difficult and painful, than that of the ligature: the only exception to this occurring in its applicability to the smaller arteries. And if it be acknowledged, as the most talented practitioners admit, and as it appears to me to have been most minutely demonstrated, that all other cirumstances being equal, there is greater probability of success when the distance between the situation of the ligature and the origin of a large collateral branch is considerable, than when it is small, the conclusion must necessarily be drawn, that torsion is not so valuable as the ligature, because it destroys the parietes of a vessel for a much greater length, and therefore proportionately diminishes the strength and length of the coagulum. For instance, if the femoral artery be wounded two inches below the profunda, and a ligature be applied immediately above the wound, a distance of twenty or twenty-two lines, which experience proves sufficient for the formation of the coagulum, will remain between this point and the large collateral branch: whilst, if torsion be used in the same part, fifteen or eighteen lines only will remain in which this process can be effected. Should the wound be situated still nearer a collateral branch, the objection has still greater weight, because it has been proved that the coagulum is not formed in such manner as to fill the artery, except when the interspace between the ligature and the first branch, upon the side which is nearest to the heart, equals eight to ten lines in length.

We shall now examine whether the immediate disadvantages which have been described as the results of this mode of operation, the torsion of an artery, are compensated by equivalent and ultimate benefits. This is far from being the case. We have already seen that the inflammation and suppuration are always as tedious, and sometimes even more so, after torsion, than after the application of the ligature: and the causes of this it is not difficult to deduce. The first, consists in the duration of the operation itself; the second, and one of the most serious, is the displacement which an artery suffers in its proper sheath, when the traction which is necessary for its due insulation is performed: and lastly, the third, is attributable to the presence of a real foreign body, capable, perhaps, of exciting a greater degree of inflammation, than the single thread which is used as the ligature. The extremity of the twisted artery, and the fragments of its internal and middle membranes, constitute this foreign body: these portions of the vessel being seriously bruised by the torsion, maintain no vital connexion with their surrounding tissues, are unable to form any adhesion with them, and can only be removed by the double effect of suppuration and absorption. Until this effectually take place, the fragments of the arterial parietes excite as extensive a degree of inflammation and suppuration, as is produced by the knot of the ligature, until it is entirely expelled: and I assert, that whenever I have applied the ligature upon the principal artery of one extremity, and used torsion upon the corresponding vessel of the other, I have nearly always observed that the wound cicatrizes more readily in the former than in the latter instance.

When torsion is performed upon the small vessels, the same disadvantages do not arise as in those just described: in the first place, because the operation requires less particularity, and secondly, because vessels of this class have not, like the large arteries, a proper and distinct sheath: and hence, if the same degree of traction be exercised upon them, the inconvenience produced by any considerable separation from the surrounding parts, does not arise: lastly, the size of the extremity of the twisted artery is very small, and as it is

necessary for arresting the hæmorrhage, that torsion should be performed but three or four times, their vitality may still remain; and, consequently, this portion of the vessel, although it is the substitute for a foreign body, does not act as a cause of suppurative inflammation,—the effect of torsion when employed upon an artery of considerable magnitude.

Although I acknowledge the benefits which the surgeons, who have suggested and put in practice the torsion of arteries, have conferred upon science, by enriching it with an additional method of arresting hæmorrhages, yet the considerations just detailed, in addition to those which have been previously given, enable me to assert, that whenever this mode is employed it ought always to be adopted with great reserve, and that it should never be used upon the large arteries.

On ossified Arteries. During the enquiry and comparison which have been made of the various modes proposed for suspending the circulation of the blood in arteries, as the first step towards effecting their ultimate obliteration, the supposition has been made that the integrity of the three membranes of which their parietes are composed, was perfect: or, at least, that if any alteration did exist, that it was only of a trifling nature: had this supposition not been admitted, the plans which have been described as the most advantageous would, on the contrary, have inevitably induced the most fatal consequences.

The morbid changes, which are capable of thus influencing the probabilities of the successful application of a ligature upon an artery, are unfortunately of very frequent occurrence: they appear to depend upon two distinct principles, one of which favours the production of cartilaginous and osseous plates, which are primarily seated between the internal and middle membranes; and the other affects the fibrous membrane alone, which it changes by successive metamorphoses into a yellow and very friable substance, the consistency of which, though at first very great, gradually diminishes, and ultimately corresponds in character with a softened tubercle. These are the

pathological conditions to which authors have applied the terms, ossification of arteries, and the transformation of the arterial parietes into a squamous and steatomatous substance.* (Appendix O.)

These altered conditions of the parietes, always produce results unfavourable to the successful application of a ligature upon an artery, when the disease is still in its infancy: and when it has reached a more advanced state, the success of the operation is rendered almost impossible, in consequence of the diminution or entire loss of the vitality of the middle and internal tunics —the cellular membrane being the only portion which partially retains this power: but since this also must be divided by the ligature, at an earlier or latter period, the adhesion which the divided edges ought to form with each other, never possesses that degree of power which is capable of resisting the impulsion of the blood, and hæmorrhage is an unavoidable termination: at least, always when the distance between the situation of the ligature and the origin of a superior collateral vessel is not very considerable. In these instances, where the length of the coagulum may be considerable, some portions of its surface remaining in contact with those parts of the artery which are healthy, in these situations it has been frequently observed to form adhesions sufficiently firm to resist the moving power of the blood, which tends to produce its displacement.

In these difficult cases, practitioners have recommended that the vessel should be examined nearer the heart, for the purpose of ascertaining if a portion of the artery cannot be found in a sufficiently healthy state to admit the performance of the operation. It will be unnecessary to remark, that the hope of finding any part of the vessel which is unchanged, can only be entertained when the patient is young; if he be aged, it is probable that the same state will be found to continue throughout.

In other circumstances, after amputations for instance, if several trunks are

* Vid. Morgagni, De sedibus et causis morborum.—Scarpa on Aneurism.—Lieutaud, Histoire anatomico-medicale.

diseased at the same time, serious inconveniences would be occasioned by any attempt to seek for another part of the vessel, upon which the ligature might be placed. It becomes then, a matter of considerable importance to ascertain what are the best means of meeting these peculiar cases, as it has been already stated that those which are the most advantageous when vessels are healthy, are under opposite circumstances, the most destructive.

If a narrow ligature, as a single thread for instance, be applied upon an ossified artery, and it be tightened so as to obliterate the cavity of the vessel, the osseous and cartilaginous plates which are lodged in its substance are broken into irregular pieces, (Pl. II. fig, 8, *b*, *b*,) the cellular tunic, which occasions an even and uniform pressure upon the divided internal and middle membranes, (Pl. I. fig. 4, *b*,) when a narrow ligature is applied upon a healthy vessel, is by these means distended, and considerably raised by the irregular edges of each portion. (Pl. II. fig. 5, *b*, *b*.)

During this state of unnatural extension of the cellular membrane, the slightest degree of suppurative inflammation will be sufficient to destroy and break it completely, from the second to the fourth day : and, the phenomena which are developed in the healthy artery almost immediately after the application of the ligature, i. e. the exudation of plastic lymph and unctuous matter, and the formation of a coagulum, either fail altogether, or are produced only slowly : therefore, under these unfortunate circumstances on the one hand, there is almost a mechanical rupture of the external tunic, produced by an unnatural extension of several different parts of its surface, and on the other, the absence of every kind of agglutinating principle between the lips of the division of the internal and middle membranes, and, consequently, a considerable retardation in the formation of the coagulum. These facts then prove that the ligatures composed of a single thread, as well as those which are formed by the union of three or four, must be positively proscribed, under any diseased alteration of the coats of the artery, because they divide the cellular membrane too rapidly. The surgeon is called upon to

apply those instruments which merely flatten the artery, and do not produce too great degree of compression, that if possible he may interrupt the circulation of the blood through its interior, without at the same time bruising and destroying the cellular tunic ; he must, in one word, endeavour to produce that very slight degree of compression which will not entirely suspend its vitality—for should the compression be too powerfully made, and the vitality of the cellular membrane be rapidly destroyed, which happens when a ligature is forcibly applied, the section is completed too speedily in consequence of the eliminatory process which is always established between the dead parts, and those which still possess life.

Whatever method is adopted, no advantage can be obtained from these altered conditions of the internal and middle membranes, they are altogether inert, and to use the expression, act as if a foreign body were placed between the cellular membrane and the column of blood ; hence they neither tend to promote the formation or organization of the coagulum, nor produce the mutual adhesion of the arterial parietes, although these membranes, when in a state of health, energetically develope the various phenomena which have been enumerated. As the external tunic, therefore, alone remains to supply the deficiency, the reason is evident, why the section produced by suppuration ought to be retarded as much as possible.

When the blood no longer flows through an ossified artery, it does not coagulate as rapidly, as when the vessel is in a normal state : for in this case, neither the plastic lymph nor unctuous matter, which, according to the description which has been given of what follows the application of a ligature upon a healthy artery, considerably facilitates the formation and increase of coagulum, by affording a point of support for its primary molecules, is exuded. The absence, moreover, of every perceptible organic process in an ossified vessel also very distinctly retards the organization of the coagulum : and thus, on the one hand, the blood not only coagulates very slowly, but on the other, even when this is effected, its adhesion to the internal membrane

and the various changes which it must undergo before it assumes the cellular state, must be dependent alone on the vitality of the blood itself. In these cases, that vital centripetal impulsion which is transmitted from the normal arterial parietes is absent, the coagulum thus seems to be placed within a tube which is comparatively inert, and is indebted to any advance in organization to the vitality of the blood alone.*

From these facts it must be concluded, that when it is required to obliterate an ossified artery, the method of compression must be adopted, a plan recommended by the most celebrated surgeons, and especially by M. *Boyer*.—*Presse-arteres* of various kinds, and the plan adopted by *Scarpa* must, therefore, be preferred to any of the others ;† and, in making the application, care must be taken not to exert too great a degree of pressure, lest the vitality of the cellular membrane, the only tunic endowed with it, be suspended.‡

The *presse-artere* cannot be used after amputations, cases in which arteries are frequently ossified: because they prevent the necessary dressings and adhesion of the wound. The only plan which can then be employed is that of *Scarpa*, or which is still better, that of *Dupuytren* and *Roux:* this consists, in introducing within the ossified artery a small portion of bougie, or any other body of tolerable consistence, and afterwards to apply an ordinary ligature round the whole. In this manner, the osseous or cartilaginous plates are neither broken nor displaced, and, therefore, cannot by any means facilitate the rupture of the cellular membrane: a state which is, to a certain extent, always produced when *Scarpa's* plan is followed. When a foreign

* Vid. Prècis èlementaire de Physiologie, second edition, par. M. le Professeur Magendie.

† M. Guthrie advocates a contrary opinion, he says, "When arteries are unhealthy the selection and proper application of a ligature are points of great importance. A *small round* ligature should be fairly, evenly and *firmly* applied, without the intervention of any substance whatever between it and the cellular covering of the artery. The secondary hæmorrhages, which are recorded by different writers, took place more from the application of improper ligatures than from any other cause." See also Mr. Porter's Cases of Aneurism—Dublin Journal of Medical and Chemical Science, vol. i. p. 35. (Trs.)

‡ Vid. Traitè des Maladies Chirurgicales, par le Baron Boyer, t. 2, p. 139, 155.

body is introduced within the vessel, the consequences correspond with what takes place when a broad ligature has been applied and a large foreign substance left within the wound: i. e. very extensive inflammation, succeeded by inflammation, arises around and within the artery. I have frequently attempted to introduce a foreign substance within the large arteries of living animals, and have invariably observed that the portion of the coagulum which was in contact with the body was reduced into a putrefactive mass, some time after its formation, (Pl. II. fig. 7, *d*,) so that, unless the distance had been considerable between the point where the ligature was applied and the superior collateral branch, hæmorrhage would have inevitably occurred: and it is moreover the best means which can be employed.

It need not be observed that whenever the arteries are cartilaginous or ossified, torsion cannot be performed: for the fragments which would be caused by the tearing and bruising of the internal and middle membranes, would immediately occasion a rupture of the external cellular membrane, or at least would render it still more certain than under any other method.

In this account of my experimental researches, I have thought it unnecessary to make any mention of ligatures of reserve: their employment has been pronounced useless for many years, and they are now no longer advocated. (Appendix P.)

On Wounds of Arteries. When the division of an artery is complete the divided ends immediately retract, and withdraw within the cellular sheath, to an extent which varies from four or five lines to an inch. The The discharge of blood having been rapid and very abundant, becomes smaller in quantity and is sometimes ultimately and completely suspended, in consequence of the great debility produced in the powers of the wounded part and the retraction of the cellular tunic, and sheath of the vessel. By this mutual collapse, these two membranes almost entirely hide the vessel from view: and causes the feeble jet of blood, which still endeavours to flow, to be divided into several smaller streamlets, which can only escape through

the cellular filaments by which the orifice of the artery is surrounded. These sanguineous jets spirt to a short distance only, and are soon arrested by the mere influence of the sinuous passages through which they are obliged to pass, the rapidity of their progress being more retarded by these means in proportion as their distance from the divided artery increases. So soon as the flow of blood is arrested in any part of these sinuosities, coagulation commences, and the clot rapidly increases by contiguous deposition, as far as the extremity of the artery: by a continuation of the same process also, as many coagula are formed as there are streamlets of blood. The whole of the coagula tend towards the extremity of the vessel, by which the blood is supplied and uniting together, from one only, which entirely prevents the artery from being seen. This single coagulum which prevents all hæmorrhage from the vessel, gradually increases in length and thickness, and is elongated internally to some extent. The developement and organization of these coagula follow the same rules, as those described when speaking of small ligatures, and thus, the cure which nature effects of a hæmorrhage produced under a transverse section of an artery, has in every respect as durable a character as that obtained by tying the vessel with a ligature.*

If after having laid an artery bare for a short distance a longitudinal incision of four or five lines in length be made in its parietes, the blood will in the first instance be discharged with violence: but it does not continue so long as to exhaust the powers of the animal. The first cause which opposes the discharge of blood is found in the retraction of the lips of the wound, which, from their elasticity, incline towards the centre of the artery; as this retraction is almost entirely the property of the middle tunic, and the cellular membrane not being elastic, this continues free and floats in the edges of the wound, in such manner that it is incessantly moved by the discharge of blood: in consequence of the friction which this contact produces, the force

* For instances of the spontaneous cessation of hæmorrhage after the wound of large arteries, see Clinique Chirurgicale, par M. le Baron Larrey, article Aneurysme.

of the sanguineous fluid is considerably diminished and the collapse of the parts which are external to the artery, is capable of breaking down this enfeebled column of blood, and spreading it through the adjoining cellular tissue. The blood which lodges in the cells forms numerous small coagula, which uniting together soon constitute one only, (Pl. II. fig. 4, *e e*,) by which the wound of the artery is closed and the discharge of blood prevented. I have never witnessed in these coagula, the pointed prolongation, which, according to J. L. *Petit*, is placed in the situation of the internal membrane, and thus contributes to form a portion of the arterial parietes ; so far from this, I have noticed the presence of a slight depression in the coagulum where the wound is situated.*

If a transverse instead of a longitudinal incision be made into an artery, to the extent of only two thirds of its circumference, the lips of the wound are widely separated from each other, and the difficulty of arresting the hæmorrhage is increased. The coagulum is formed in a different manner, and assumes also another figure. When the animal is much debilitated, and the blood scarcely any longer flows, in consequence of its extremely depressed condition, a small flattened coagulum forms on the lips of the wound, (Pl. II. fig. 6, *d*, *d*,) which gradually extending itself from the circumference to the centre, terminates in complete closure of the vessel : but I have remarked that it never acquires as much thickness as those which are formed in a longitudinal wound : in common with these it leaves the cavity of the artery perfectly open, and, consequently, only effects a temporary cure.

From these statements it appears that when the wound of the artery is simple, hæmorrhage may be arrested without producing any obliteration of the vessel : but no advantage is derived from this, for the cure is only apparent—a blow upon the part, violent exercise of the extremity, or very powerful impulsion of the blood, are causes capable of producing a rupture or

* This difference is attributable, I think, to the short time which elapsed between my experiments and the examination of the preparation. J. L. Petit not having made his until a considerable length of time after the wound of the artery.

displacement of the coagulum, and thus of reproducing the hæmorrhage. Whilst if the artery has been completely divided, a coagulum is formed in its interior, which will obliterate the vessel in a firm and permanent manner, if nothing occur to arrest the progress of its organization. (Appendix Q.)

By whatever mode the transmission of the blood in the principal artery of a limb is effected, a certain number of precautions must be attentively regarded for securing the continuance of the circulation below the part where the ligature has been applied, and which a prudent surgeon will never neglect : but, as they are fully insisted upon in every general pathological work, it appeared to be unnecessary to repeat them in this place. It shall only be remarked that venesection ought to be very carefully employed, the kind of plethora which is sometimes found after the tying of a large arterial trunk is required to force the transmission of the blood out of the capillaries which are above, into those below the ligature. Sanguineous evacuation is only serviceable when the patient is threatened with the congestion of some important organ.

DEDUCTIONS.

In accordance with the general considerations which have been detailed, from the results of a considerable number of experiments performed upon living animals, as well as observations made upon man; the following principles may be laid down as general rules, which ought to direct the surgeon when making the application of a ligature upon an artery.

1. It is necessary towards effecting the obliteration of an artery, that the transmission of the blood through its interior, should be entirely suspended.

2. This obliteration is accomplished with greater rapidity and less danger by dividing the internal and middle tunics, than by preserving their integrity.

3. The closure of an artery is more facilitated by the clean and regular section of the internal and middle membranes, which is produced when a small round thread is used as the ligature, than by the broken and irregular division formed by the application of a flat and broad ligature, whether large or small.

4. The means which nature adopts in permanently closing a vessel upon which a ligature has been applied, are of two kinds: 1. The adhesion of the parietes of the vessel to each other: 2. The formation of a coagulum of blood, which, so soon as it is sufficiently large to fill the vessel, becomes adherent to its internal surface.

5. As the phenomena which immediately succeed the operation of applying a ligature upon an artery, and must continue until obliteration is perfect, all other things being equal, bear a direct ratio to the vitality of its parietes, it is

of the utmost importance that the surgeon do not insulate the vessel to a greater extent than is absolutely necessary for placing the thread around it, in order that their vitality may not be diminished.

6. The adhesion of the parietes of an artery to each other, can only occur when its tunics enjoy their vital properties; when these are extinct, no adhesion is procured, and when they are reduced it is very feebly formed.

7. No coagulum is formed in a tied artery when the ligature is placed very near a large collateral branch, if it arise from the side nearest to the heart.

8. The means which nature, in the first instance, uses for the prevention of hæmorrhage, after the decidence of the ligature, such as, adhesion of the opposite parietes of the artery, or the agglutination of the lips of the divided internal and middle tunics, when a section of these have been made, are invariably destroyed, either totally or partially, by the suppuration which takes place to detach the ligature.

9. The base of the secondary coagulum, generally in contact, and adherent more or less with the agglutination of the arterial parietes, is also almost invariably disorganized and destroyed by the same suppuration; and would thus be displaced, and give rise to an immediate hæmorrhage, if it were not of a certain length, or if the union formed with the arterial parietes were not sufficiently powerful to resist the impulsion of the blood. When the ligature is applied too near a collateral branch, the formation of the coagulum is either too small or altogether prevented, and when the membranes are diseased, or the vessel has been teazed and too extensively insulated during the operation, the union with the arterial parietes is either destroyed altogether or very feeble in character.

10. The adhesion which has been once established, is capable of being destroyed by an extension of the suppuration from the surrounding parts and surface of the artery towards its centre.

11. The entire substance of the coagulum itself may be destroyed, if the inflammation is very active, and even before the separation of the ligature.

12. Under these circumstances, if a considerable space is not found between the superior portion of the coagulum, (the base of which has been destroyed,) and the origin of a large collateral vessel, hæmorrhage will inevitably take place : on the contrary, a new coagulum will be formed, and pass through the same changes as the first, if its developement be not arrested.

13. The principal causes of suppuration, which entail consequences so serious, are the length of time occupied in the operation, the manipulation of the surgeon when ascertaining the various organs with which he is engaged, the bruising of these parts, the insulation of the artery for too great an extent, or even its mere disturbance for a short distance by locomotion in its proper sheath, and, lastly, the nature and size of the body which is left upon the artery or within the wound. Independently of these physical and material causes, others sometimes occur which are connected with the permanent or temporary state of the individual upon whom the operation has been performed, and which it is frequently impossible to appreciate.

14. From what has just been advanced respecting the causes of suppuration and the remarks made in the third corollary, it must be inferred, that round and small ligatures ought to be preferred to those of every other kind.

15. Whatever be the nature of the ligature applied, it is never absorbed : should the external wound cicatrize before it escapes, consecutive abscesses always take place until it has been expelled.

16. The mere division of the internal and middle tunics by a small ligature is insufficient to obliterate an artery : it is still necessary that its application should be continued upon the vessel, for the purpose of maintaining the lips of the section in apposition and supporting the primary rudiments of the coagulum. (Pl. I. fig. 11.)

17. When the internal and middle tunics of an artery have been divided, the continuance of the ligature upon an artery, though maintained for some hours, is in the human subject incapable of effecting its closure : in animals, even as for instance in dogs, in whom the blood possesses great plasticity,

union is only very rare. On the one hand, the adhesion of the arterial parietes to each other is so feeble in the first five or six hours subsequent to the operation, and on the other, the coagulum is so small, that the impulsion of the blood and disturbance of the parts, which the retraction of the thread occasions, displaces the one, and destroys the other.

18. When a coagulum is displaced and carried away by the column of blood, its size is rapidly diminished in consequence of its motion in the artery, and if its attachment in the interior be such that a portion of blood can glide between it and the artery, it is soon reduced by repeated friction. If on the contrary, it fill the artery entirely, or occupies a collateral branch, these vessels become obliterated.

19. It is a longer and more difficult operation effectively to employ torsion in a large artery, than to apply a ligature upon it.

20. When torsion is employed, traction must be performed upon the vessel so as to insulate it for six or eight lines: this displacement extends at least as far as the first large collateral vessel, the continuity of the vessel with its proper sheath, is thus broken throughout its entire length; and unpleasant consequences as we have seen result. This separation is of no importance in the smaller arteries, because they have not a very distinct sheath, and further, because they usually give off more branches in a given length of vessel.

21. In consequence of the bruising and trituration which torsion occasions in the arterial parietes, some portions of its component membranes are destroyed and deprived of vitality. These become a cause of inflammation, which in addition to the longer and more painful manipulations of the torsion, than of the ligature, terminate in producing a suppuration which is equally as great and lasting as that which can be caused by the application of a ligature.

22. When an artery is divided at a short distance from a large collateral branch, which is situated between this and the heart, torsion is less effective

than the ligature, because it destroys the artery to a greater extent, and, consequently, diminishes in proportion, that space which is necessary for the formation of the coagulum.

23. The disadvantages arising from torsion, are not so great in small as large arteries.

24. When an artery is ossified or cartilaginous, the formation of coagulum only must be calculated upon for effecting its closure. If that portion upon which the operation has been performed is near a collateral branch, the operation will not succeed. In this instance, the ligature should be applied above it, or the branch should be tied at the same time with the trunk. This rule may be applied with equal advantage when tying arteries which are not diseased.

25. When hæmorrhage ceases spontaneously, after the complete division of an artery, the surgeon will take care to remove all the causes which might disturb the formation and organization of the coagulum, and, to abstain from every kind of operation, at least, so long as he believes that the propinquity of a large branch with the wounded part is not such as will prevent the developement of the coagulum : under these circumstances, the artery must be denuded, and a ligature applied above the collateral branch.

26. When an artery has been opened, either longitudinally or transversely, although hæmorrhage may have spontaneously ceased, the surgeon must invariably lay the vessel bare, and tie it, because in these instances, as the coagulum is situated externally to the artery the closure is only temporary.

EXPLANATION OF PLATES I. & II.

SHEWING THE EFFECTS AND CHANGES PRODUCED BY THE APPLICATION OF LIGATURES OF VARIOUS KINDS UPON AN ARTERY.

Explanation of Plate I.

Ligature of the Crural Artery with a single thread; examined forty-eight hours after the operation.

Figure 1.

A Portion of the Femoral Artery.

a Extremity towards the heart. *b* Section of the internal and middle tunics by the ligature. *c* Superior coagulum. *d* Areolar tissue of the new formation, uniting the coagulum to the parietes of the artery. *e* Fibrinous prolongation of the superior coagulum. *f* Inferior coagulum. *g* Tissue of plastic lymph uniting the inferior coagulum to the inferior lip of the section of the arterial parietes.

Ligature of the Primitive Carotid of a Dog: examined twenty-eight hours after the operation.

Figure 2.

The left Primitive Carotid Artery.

a Cardiac side. *b* Inferior ligature composed of four threads. *c* Trace of the section of the internal and middle tunics, made by a single thread, removed immediately after its application.

Figure 3.

The same Artery opened.

a Section of the internal and middle tunics, made by the flat ligature. *b* Coagulum on the side towards the heart. *c* Section made by the single thread which was not left upon the artery. *d d* Coagulable lymph forming bands between the lips of the section. *e* Coagulum situated between the two ligatures. *f* Areolar tissue adhering to the internal surface of the artery.

FIGURE 4.

The Primitive Carotid Artery.

a Side towards the heart. *b* Ligature practised with a single thread. *c* New formation uniting the ends of the artery.

FIGURE 5.

The same Artery opened.

a Side towards the heart. *b* Sanguineous coagulum. *c* Lymph adhering to the inferior lip of the section of the arterial tunics, and to the superior extremity of the coagulum. *d* Superior portion of the section.

FIGURE 6.

A Portion of the Crural Artery, tied with four united threads: examined on the fourth day.

a Extremity towards the heart. *b* Section of the internal and middle tunics by the ligature. *c c* Lips of the section. *d* Superior coagulum. *e* Inferior coagulum very large. *f* Origin of the femoral profunda.

The Primitive Carotid Artery tied with a single thread: examined on the sixth day.

FIGURE 7.

A Portion of the Primitive Carotid Artery.

a Side towards the heart. *b* Tissue intermediary to the two ends of the artery. *c* Inferior coagulum. *d* Superior coagulum. *e* Inferior lip of the section of the arterial parietes, adhering around the base of the coagulum (the rest of the union of the coagulum to the sides of the artery, is slight, that is to say, the organization of the new cellular tissue is not yet very apparent.) *f* Superior lip of the section of the artery; the cellular tissue surrounding this part of the artery is in a state of suppurative inflammation, the sides of the artery and the coagulum which it contains are covered with suppuration, and at the point *d* the coagulum is disorganized. *g* Purulent matter.

Ligature of the Crural Artery with two simple Ligatures, situated about four lines from each other. Section of the Artery between the two Ligatures: examination made on the sixth day.

FIGURE 8.

A Portion of the Crural Artery.

a Side towards the heart. *b* Tissue intermediary to the ends of the artery. *c* Superior coagulum, its base united with the sides of the artery; the thread still slightly holds the vessel. *d* Inferior coagulum. A severe inflammation has almost entirely effaced the organization of this coagulum, and destroyed its adhesions with the sides of the artery.

FIGURE 9.

Ligature of the Primitive Carotid Artery with a band of four threads, and with the interposition of a small piece of diachylon, which was removed five hours afterwards: examined on the tenth day.

a Side towards the heart. *b* Tissue intermediary to the two ends of the artery. *c* Inferior end. *d* Superior end. *e* Sanguineous coagulum. *f* Second coagulum of blood. *g* Conical prolongation of the inferior end. *h* Conical prolongation of the superior end.

Ligature of the Crural Artery with a broad tape of four lines: examined on the eighth day.

FIGURE 10.

A Portion of the Crural Artery.

a Extremity towards the heart. *b* Tissue intermediary to the separated ends of the artery. *c* Inferior lip of the division, (the superior, from the effect of suppuration, cannot be distinguished from the intermediary tissue.) *d* Superior coagulum. *e* Inferior coagulum. *f* Lymph applied around the base of this coagulum, and uniting it to the sides of the artery. (The centre of the coagulum is yet sanguineous.) *g* Filamentous

tissue uniting the surface of the same coagulum to the sides of the artery. The same phenomena have not taken place on the superior end, on account of the presence of the ligature on that part, producing a suppurative inflammation occupying both the end of the artery and the base of the coagulum: this inflammation has destroyed both. We see rather more of the interior of coagulum *d*.

Figure 11.

A Portion of the Primitive Carotid Artery, upon which two single Ligatures have been applied, and removed immediately afterwards; examination made on the fifteenth day.

a Side towards the heart. *b b* Section of the internal tunics, by means of the ligature. *c c* Plastic lymph, and beyond a little cellular tissue, interposed between the lips of the section of the arterial parietes.

Ligature of the Crural Artery with a band composed of four threads: examined on the tenth day.

Figure 12.

The Crural Artery: superior end.

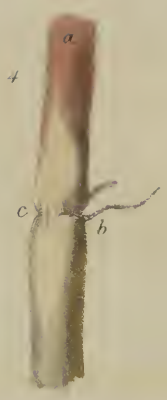
a Section of the three arterial tunics. *b* Sanguineous coagulum.

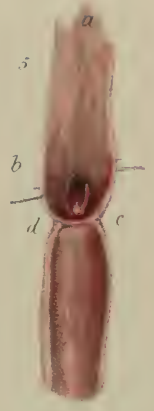
Figure 13.

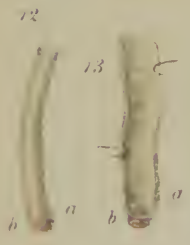
The same Artery opened.

a Superior part of the coagulum. *b* Small portion of the sides of the artery which have not been opened, in order to exhibit the small extent of their adhesion with the coagulum.

PL. I.







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Explanation of Plate II.

Figure 1.

Ligature of the two Primitive Carotid Arteries : examined on the tenth day.

a Aortic artery. *b* Primitive carotid of the left side, upon which two single ligatures have been applied. *e* Ligature on the side towards the heart. *f* Inferior lip of the section of the internal and middle tunics. *g* Superior lip of the same section. *h* Intermediate tissue, formed in the greater part by the cellular coat. *i* Sanguineous coagulum. *j* Ligature on the side of the capillaries. *k* Inferior lip of the section of the internal and middle tunics by the ligature. *l* Superior lip. *m* Inferior sanguineous coagulum. *m* Superior coagulum.

c Carotid of the right side tied by four united threads. *n* Inferior lip of the section of the internal and middle tunics. *o* Superior lip of the same section. *p* Tissue intermediate to the two lips, formed by the cellular coat. *q* Areolar tissue of new formation, uniting the top of the coagulum to the cellular coat. *r* Coagulum towards the heart. *s* Band of plastic lymph from the cellular coat to the top of the coagulum. *t* Coagulum on the side of the capillaries. *u* Adhesion of this coagulum to the edge of the section of the internal and middle tunics.

Ligature of the Primitive Carotid, including a piece of diachylon between the band (two threads united) and the Artery : examined on the fifteenth day.

Figure 2.

A Portion of the Primitive Carotid Artery.

a Extremity towards the heart. *b* Pneumo-gastric nerve adherent to the artery. *c* Tissue intermediary to the ends of the vessel. *d* Superior part of the inferior end.

e Inferior part of the superior. *f* Coagulum towards the heart. *g* Coagulum on the side of the capillaries.

Figure 3.

A Portion of the Primitive Carotid upon which two large Ligatures have been separately applied: examined thirteen days after the operation.

a Side towards the heart. *b b* Tissue intermediary to the lips of the two sections. *c* Coagulum on the side of the heart. *d* Coagulum on the side of the capillaries. *e* Middle coagulum situated in the portion of the artery included between the two ligatures. *f f f* Areolar tissue uniting the surface of the coagula to the arterial parietes. The subject of this experiment throughout the whole arterial system was inflamed and red.

Figure 4.

A Portion of the Crural Artery upon which a longitudinal incision from four to five lines has been made: examined twelve days after the operation, the exterior wound being cicatrized.

a Side towards the heart. *b* Cavity of the artery. *c* Opening made at the anterior part of the artery, considerably narrowed. *d* Centre of the coagulum which stopped this opening. *e e* Circumference of this coagulum.

Figure 5.

A Portion of the Crural Artery ossified.

a Ligature applied upon this artery. *b b* Projections formed by the edges or angles of the osseous plates broken by the ligature.

Figure 6.

A Portion of the Crural Artery cut transversely in two thirds of its circumference: examined six days after the experiment.

a Side towards the heart. *b* Cavity of the artery. *c c* Lips of the incision made

into its sides. *d d* Fibro-cellular tissue adherent to those lips and prolonged unto the centre of the opening.

Figure 7.

A Portion of the Primitive Carotid tied with a double thread, applied upon a foreign body previously introduced into the cavity of the vessel: examined six days afterwards.

a Side towards the heart. *b* Cavity of the artery. *c* Place where the foreign body introduced into the interior terminates. *d* Sanguineous coagulum softened and almost in suppuration. (The artery had been previously tied above the opening by which the foreign body was introduced, in order to prevent hæmorrhage, which would not fail to have taken place from the superior end.)

Figure 8.

The ossified Crural Artery of Figure 5, *opened.*

a Groove, representing the division of the internal and middle tunics caused by the ligature. *b b* Fragments of osseous plates.

Figure 9.

The external Iliac Artery of Figure 10, *opened.*

a Shreds or fragments of the internal and middle tunics. *b* Cellular coat upon which are seen some circular fibres of the middle tunic. *c* Cavity of the artery.

Figure 10.

A Portion of the external Iliac Artery, upon which torsion has been applied.

a Depression produced by the forceps with which the torsion is practised. *b* Projection formed by the divided internal and middle tunics.

Figure 11.

A Portion of the external Iliac Artery, upon which torsion had been practised after the method of M. Amussat.

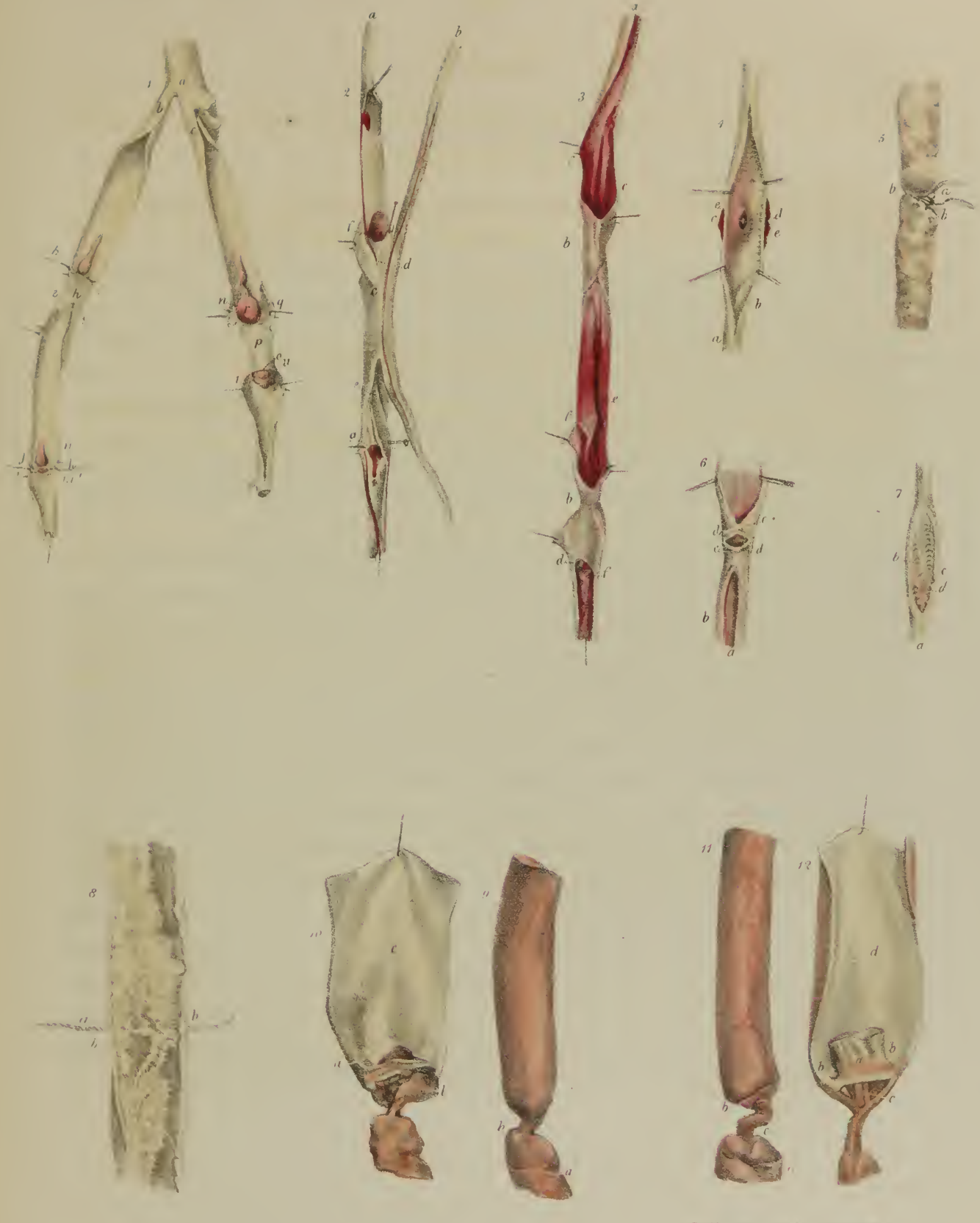
a Depression caused by the torsion forceps. *b* Point where the inversion of the internal and middle tunics cease. *c* Cellular tunic alone twisted.

Figure 12.

The same Artery as that of the preceding Figure, but opened.

a Internal and middle tunics inverted upon themselves. *b b* Cul de sac produced by this inversion. *c* Cavity of the cellular coat opened and slightly twisted. *d* Cavity of the artery.

PL. II.



Appendix F.—Page 59.

On Acupuncturation of Arteries.

In addition to the methods of procuring the obliteration of an artery which *Manec* has described in the text, it will only be right to mention a proposal of *Velpeau's* for effecting the same object: although it bears no reference to the application of the ligature, or the use of any kind of *presse-artere*;—it will probably not be considered out of place, in as much as, valuable as the ligature is for the obliteration of an artery, it may be the case, that the suggestion which *Velpeau* has thrown out may, in some cases at least, render its application altogether unnecessary. He applies to the plan which he proposes the term of Acupuncturation of Arteries. He says,

"Whilst I was attempting, some years ago, to separate the femoral artery in a dog, from its accompanying vein, with a pin, some one entered the room, and I was obliged to desist from my operation at the time. By a sudden motion of the animal the pin penetrated the artery, and was lost in the substance of the limb: it remained in this situation for a period of five days. Upon a careful examination of the parts, I was satisfied that the vessel had been obliterated by means of the puncture: a consequence which although it excited my surprise, and at first appeared to be very extraordinary, I was soon enabled to explain in a perfectly satisfactory manner. For if it be correct, that the mere application of a ligature for one or two hours, upon the largest arteries, is capable of effecting an obliteration of their calibre, as *Jones, Hutchinson, Travers*, and others have asserted, it must be possible to produce a similar effect, by exciting in a given portion of the canal, some morbid process, which is calculated to arrest the progress of the fluid by which it is distended, and induce its coagulation. Believing that the contractions of the heart exert less influence upon the circulation of the blood, than is usually supposed, I soon began to comprehend, how a foreign body of even very small size, which permanently transfixes any vascular canal, or projects in any degree through its internal surface, may be capable of producing the same consequences as the application of a ligature.

For instance, if any spicula, or bony, or calcareous lamella, which is separated on one side and adherent by the other, is thrown across, or projects into the artery in which it is developed, it is natural to suppose, that it will become the centre or radicle of a fibrous concretion, sufficiently large to deaden, materially, the impulsion of the blood, and ultimately to occasion the obliteration of the vessel. From observations published by *Turner*, and others, which have been communicated to me by Dr. *Carswell*, as well as from many I have individually made, this may undoubtedly be received as a fact: and what I have stated respecting any osseous substance, is evidently applicable to projections, asperities, or inequalities of every description, and to such as are occasioned by some rupture, as for instance, a deposit of fibrine or plastic lymph, or some vegetation—in a word to every thing, which in one mode or other diminishes the normal regularity of the canal which the blood is compelled to permeate.

As I am aware that these arguments may be attacked, in more respects than one, I shall merely state, without wishing to attach any undue importance to the subject, that being determined to submit the correctness of the principle to some test, I was anxious to ascertain whether it would be possible, intentionally, to produce the result which I had accidentally procured in the experiment which has just been related.

During the month of June, in the last year, I made some trials of this nature. An acupuncturation needle, one inch and a half in length, was inserted over the course of the artery, in the thigh of a dog, without making any previous dissection: two others were then placed in the opposite side, for the purpose of observing whether any different results took place. When the parts were examined on the fourth day, I found the first needle in the external third of the femoral artery, and that it was only partially obliterated. Of the two latter, one had passed through the vessel, which was entirely obliterated by a solid coagulum about an inch long, in the middle of which the second was found fixed.

These experiments were repeated in the November following, again in February, 1830, and since that in April last by M. *Nivert*, who at that time prepared the subject for my course of lectures upon the operations. They have been even still more recently performed at the Hopital de l'Pitie, and invariably with the same results.

To prevent the possibility of not reaching the artery, in my late experiments, I have always taken the precaution of laying it bare: sometimes I have only used one needle, at others, I have employed two or three, according to the size of the artery upon which the operation was to be performed. Whenever the foreign body has been retained four days in the vessel, a coagulum has formed in the punctured part, and an obliteration of the canal succeeded, with the exception of the aorta, which undergoes no change when thus treated: but as the needles only continued something more than twenty hours, I did not consider this conclusion final.

It must be observed, however, that hitherto my experiments have been made upon dogs of small size, and that the femoral artery is the largest upon which I have experimented:* it is necessary that they should be repeated and varied upon the larger animals, the horse for instance, before correct inferences can be deduced, and they can be applied to man under disease. It must, however, be added, that from the statement of M. *Gonzalez*, my experiments as repeated by M. *Amussat* have not been followed by the same consequences.

A single pin or needle, has appeared sufficient for arteries not exceeding the size of a writing quill; two or three may be required for such as are considerably larger, and nothing would forbid the use of four or even five in those of the largest calibre: but when several are used it is better to place them at a distance of four or six lines from each other, and in a zig-zag rather than a straight direction.

If the same effects may be anticipated in the human subject, the greatest and most self-evident advantages would accrue: instead of the risk of injury to the nerves or veins being a cause of fear, and instead of the minute and frequently dangerous dissection which the use of the ligature, torsion, &c. require; upon this plan all that is necessary as preliminary in effecting the obliteration of a vessel is to expose one surface, to as small an extent as possible, and without causing the least displacement. Probably the most formidable aneurisms may be cured, and amongst the rest those of the thigh and popliteal space, without any division of the skin, but, by merely puncturing the femoral artery in the groin with a common pin, an acupuncturation needle, or metallic wire of some kind, or by passing the foreign bodies in several

* The same experiments have been repeated in England upon dogs, by Phillips, see his Pamphlet, 1832.

directions through the aneurismal sac itself: but I much apprehend that the puncture will follow in the fate of the seton, torsion, suture, and the tearing of vessels, and that the ligature will continue to maintain its pre-eminence, notwithstanding the pre-possesions which several in every respect very praiseworthy practitioners entertain in favour of this plan." VELPEAU, vol. i. p. 126.

APPENDIX G.—Page 65.

On cutting Ligatures close to the knot.

" THE effects of the ligature on a living artery, and the consequences of its application, were not known until very recently; the principle that should govern its employment, would not therefore be understood. Dr. *Jones* undertook an experimental investigation of this subject, and has explained it in a clear and satisfactory manner, which makes us deplore his premature death as a loss to science. He has banished the use of thick and broad threads, of tapes, of reserve ligatures, of cylinders of cork and wood, linen compresses, and all the contrivances, which employed as securities against bleeding, only served to multiply the chances of its ocurrence. The use of the ligature, therefore, under the modifications suggested by our present knowledge of the processes of nature, may be considered to have arrived at perfection.

Ligatures, however, being foreign bodies in contact with the surface of the wound, must irritate, must cause inflammation and suppuration. In amputations, where it is necessary to secure many vessels, a large portion of the wound is exposed to this irritation; its union is retarded, and considerable pain and spasm are sometimes produced. Are these evils inseparable from the use of ligatures? or, is there any plan by which we can avoid them? I think that there is; and I shall proceed to state to the society the trials I have made, and the experience which my practice has furnished on this subject.

The method I have adopted consists in tying the vessels with fine silk ligatures, and

cutting off the ends as close to the knot as is consistent with its security. Thus the foreign matter is reduced to the insignificant quantity which forms the noose actually surrounding the vessel, and the knot by which that noose is fastened. Of the silk which I commonly employ, a portion sufficient to tie a large artery, when the ends are thus cut off, weighs between $\frac{1}{50}$ and $\frac{1}{60}$ of a grain: a similar portion of the thickest kind I have tied weighs $\frac{1}{20}$ of a grain, and of the slenderest $\frac{1}{100}$. These ligatures do not interfere with the process of adhesion, and we shall hardly entertain any serious apprehension that substances so minute will excite any subsequent irritation and disturbance.

That kind of silk twist, which is commonly known in the shops by the name of dentist's silk, and which is used in making fishing lines, is the strongest material I know of, in proportion to its size, and, therefore, the best calculated for our purpose, which requires considerable force, in drawing the thread tight enough, to divide the fibrous and internal coats of the arteries. This twist is rendered very hard and stiff by means of gum, which is applied to it in the process of its manufacture, and may be removed by boiling it in soap and water. This latter process loosens its texture, elongates it and makes it weaker, so that after boiling, we can break with the fingers a thread, which could not have been so broken before.

The stoutest twist, which I have used, is a very small thread, compared to the ligatures made of incle, which are commonly employed at St. Bartholomew's Hospital: I cannot however break it with my fingers and thumbs, although a great force may be applied in this way, by winding the thread around the ends of the fore-fingers, and drawing it over the ends of the thumbs, as in the ordinary method of tying the arteries. The quantity of such a thread, necessary for the noose and knot, on the iliac artery, weighs $\frac{1}{20}$ of a grain: or, if the gum has been removed, about $\frac{1}{26}$. But the finest twist kept in the silk shops is strong enough, in its hard state, for any surgical purposes; and the noose and knot would not weigh $\frac{1}{40}$ of a grain. The finer kinds of silk, if used very cautiously, will answer the end extremely well; but their breaking so easily is an objection to their common employment.

When the ends of the ligature are cut off close to the knot, it will be asked, what becomes of the ligatures? Do they come away with the discharge, or remain where they are placed? In the latter case, do they lie quietly in the parts? Are they surrounded by a cyst containing matter? Or may they be absorbed? The results

of some experiments in dogs, which I shall relate in speaking of the operation of aneurism, shew that these ligatures do not separate very quickly. If they remain where they are placed in the human subject, as long as in these brutes, they must undoubtedly be inclosed by the union of the sides of the wound, and they could be discharged afterwards only by exciting irritation and suppuration. I apprehend that the layer of lymph which is so quickly effused on cut surfaces, covers and incloses these small threads which must, therefore, be retained in the wound. At all events, I have not seen them come away; but hitherto no opportunity has occurred to me, of examining the parts at a sufficient length of time from their application, to throw any light on their ultimate fate. In no case has there been any abscess after the healing of the wound; nor any other symptom that could be ascribed to these ligatures.

In a work on gunshot wounds and amputation, published sometime after I had begun to use the silk ligatures at St. Bartholomew's Hospital, Mr. *Guthrie*, an army surgeon, mentions that the practice of cutting off the ends of the ligatures close to the knot, has been lately adopted by some military surgeons, both French and British. When the wound has quickly healed, the knots have been subsequently discharged at small abscesses. Several cases treated this way have ended successfully: and, in particular, many under the care of Professor *Delpech*, of Montpellier. In two or three instances, Mr. *Guthrie* saw ill-looking abscesses formed by them. As this statement is not accompanied by any description of the materials or size of the ligature, nor by any details of the unfavourable cases, we cannot judge whether the events alluded to are to be attributed to the method itself or to the way in which it was executed.

During the last ten months I have employed this method of securing the arteries in ten or eleven cases of amputation, in six operations of the breast, and in the removal of two testicles. The cases all did well, excepting a man who lost his thigh, and who died of an affection of the lungs; the wounds healed readily and nothing was seen of the ligatures.

If this plan should not be found entitled to the important praise of promoting adhesion, and of securing the arteries in a safe and effectual manner, which, however, my present experience convinces me that it deserves, still, as it supersedes the necessity of threads hanging out of the wound, the management of which is so often troublesome and painful, it may be recommended, on the grounds of superior convenience to the surgeon, and comfort to the patient." LAWRENCE, Med. Ch. Trs. vol. vi.

Appendix H.—Page 68.

The Effects of the Application of a Ligature to an Artery.

"The effects of tying an artery properly, appear to be the following:

1. To cut through the internal and middle coats of the artery: and to bring the wounded surface in perfect apposition.

2. To occasion a determination of blood on the collateral branches.

3. To allow of the formation of a coagulum of blood *just within the artery*, provided a collateral branch is not very near the ligature.

4. To excite inflammation on the internal and middle coats of the artery by having cut them through, and consequently, to give rise to an effusion of lymph, by which the wounded surfaces are united, and the canal is rendered impervious: to produce a simultaneous inflammation on the corresponding external surface of the artery, by which it becomes very much thickened with effused lymph: and at the same time, from the exposure and inevitable wounding of the surrounding parts, to occasion inflammation in them, and an effusion of lymph, which covers the artery, and forms the surface of the wound.

5. To produce ulceration in the part of the artery around which the ligature is immediately applied, viz. its external coat.

6. To produce indirectly a complete obliteration not only of the canal of the artery, but even of the artery itself to the collateral branches on both sides of the part which has been tied.

7. To give rise to an enlargement of the collateral branches." Jones, p. 163.

Appendix I.—Page 82.

On the Obliteration of Arteries by Adhesion of the Internal Tunics.

"M. *Deschamps* says, 'that every surgeon has a particular opinion of his own, with regard to the manner in which the cavity of an artery is obliterated; but that every surgeon, if he is a man of integrity, will agree that we have not as yet any positive and well determined practical knowledge on this subject.' I on the contrary find, that with regard to this point, there can be but one opinion, and I think, that this opinion is firmly supported by practical observations, and by certain and constant facts, and that it is proved by daily experience in that part of surgery which relates to the cure of wounds by the first intention. There is nothing more manifest and better known in surgery, than that the *adhesive* inflammation is the principal means by which the parts divided in the living solid, as well as those organically separated, when kept in mutual contact, contract a firm adhesion to each other. * * * * * *

It is the adhesive inflammation which sometimes after venesection, causes the obliteration of the divided vein for a certain space, and if this inflammation passes beyond certain limits at the place of the bleeding, and is changed into *suppurative*, it occasions a small abscess where the vein was opened, which is ascribed by ill-informed surgeons improperly to some defect of the lancet, or to the puncture of some nervous or tendinous filament. It is this process of adhesive inflammation which nature, by itself alone, or assisted by art, employs for agglutinating, and uniting firmly together, the two opposite parietes of an artery, whenever the internal surface of these parietes is placed, and kept in firm contact by means of some accidental pressure, or by a methodical bandaging; and there is no essential difference in the process of adhesion between the lips of a simple wound, or between the surface of an intestine with the peritoneum, or of the vaginal coat of the testicle with the albuginea, and the manner of union of one side of an artery with its opposite side.

In order that the compression may produce the union of the two opposite sides of an

artery with each other, and at the same time the *radical* cure of the aneurism, it is therefore necessary, that, besides the state of vitality of the coats of the artery, of which I shall speak afterwards, the degree of pressure applied upon the artery, be such as to place the two opposite parietes of the injured artery in firm and compact contact, and that it be at the same time capable of exciting the *adhesive* inflammation in the proper coats of the artery. Without the concurrence of these circumstances, the compression does not prove beneficial, or only produces an incomplete cure: for whenever the compression is not sufficient to place the two opposite sides of the artery in complete and firm contact, and does not excite in them the *adhesive* inflammation; and when the inflammation affects only the cellular substance surrounding the artery, and the parts contiguous to it, this cellular substance and these parts only contract an adhesion with each other, and are converted into a hard, compact substance, while the canal of the artery remains open and pervious as before the use of the compression." Scarpa on Aneurism. Wishart, p. 216, &c.

Appendix K.—Page 87.

On the Effects of the Application of the Compressor to Arteries.

From experiments made upon animals, Mr. *Travers* draws the following inferences.

1. "The compressor, like the ligature, effects the obliteration of an artery by exciting inflammation upon its internal tunic.

2. The operation of the compressor differs from that of the ligature in not producing a lesion of the inner coats, and, therefore, exciting inflammation upon a continuous surface.

3. The operation of the compressor is slower than that of the ligature. The former, applied for thirty hours, leaves an inflammatory blush, or a pellicle of lymph upon the inner coat, while the latter, applied for only twelve hours, is found to have obstructed the vessel by lymph; again, the former, applied for six hours, has produced no apparent

sign of the adhesive process, when examined at the end of seventy hours; whereas the latter, applied for the same time, and examined after the same interval, is found to have effected the complete obstruction of the artery.

4. The effusion of lymph after the application of the compressor, where the obstruction of the artery has been accomplished, is *en masse* to the extent of the part compressed, which is marked by a deep indentation of the walls of the vessel to which the lymph firmly adheres. The mass is of least firmness in the centre, when it is mixed with the red particles of the blood.

5. The application of the compressor, for a period of twenty-five hours, is followed by a sloughy state of the external coat of the vessel.

6. The compressor left upon the artery is liberated by ulceration, in about four days; the adjoining portions of the vessel, being previously secured by the adhesive process, present solid conical extremities. The effacement of the compressed portion of the artery is complete; and the appearances correspond precisely with those produced by the application of two ligatures, distant half an inch, more or less, upon a portion of artery denuded of its sheath, in which the internal sloughs and disappears. I may observe that when the vessel is left undetached from its sheath in the interval of the ligatures, the tube remains, and although shrunk, continues to be nourished.

7. The organization by blood vessels of the lymph obstructing the tube, is distinctly visible in a fortnight after the application of the ligature or compressor.

It appears, then, that the operation of the compressor and ligature, applied each for one minute, is that of simple pressure opposed to simple wound. If they are applied for a longer time, it is simple pressure opposed to wound and pressure combined. It is undeniable, from these experiments, that the latter is a more powerful instrument for effecting the object in view; and this result of the combination is equally conformable to reason and to experience." MED. CH. TRANS. vol. vi.

Appendix L.—Page 88.

On the Causes of secondary Hæmorrhage.

"As in all other cases in which it is proper to tie one of the great arteries of the second order, so in the new method of curing popliteal aneurism, one of the accidents which is more than any other to be dreaded, is *secondary* hæmorrhage, whether it happens from over anxiety to remove the ligature, or from a premature laceration of the proper coats of the artery, brought on by too tight a ligature. This severe accident happened repeatedly to Mr. *Hunter* himself, after the ligature of the *superficial* femoral artery, and has happened to many other skilful and celebrated surgeons after him; and it is a fact well worthy of mature reflection, that this disaster, for the most part, occurs between the tenth and fourteenth day after the operation.

Reflecting on this very important point of the cure of popliteal aneurism, and considering at the same time, that *secondary* hæmorrhage very rarely, or never happens, in consequence of the ligature of the *superficial* femoral artery after amputation of the thigh, in which this artery is drawn out and tied separately: and that on the other hand, this disaster was very frequent after amputation of the thigh, when the surgeons were in the habit of perforating the flesh with a crooked needle, and of tying the artery along with a great quantity of muscular and cellular substance, I think we may from thence justly conclude, that the *secondary* hæmorrhage, in the case of aneurism, may be ascribed to the one or other of the two following causes, viz. to the inaccuracy of the surgeon in separating the artery from the cellular sheath in that portion over which he intends to apply the ligature, or, to the too great force which he employs in tightening the artery circularly. The union of the two opposite sides of an artery as I have mentioned several times only takes place by means of the *adhesive* inflammation, to excite which, and in order that it may produce the desired effect, it is necessary that the artery be not insulated too much, or beyond the limits of the ligature: that the degree of pressure be such as to put and keep the two opposite sides of it in complete and firm contact: that the irritation caused by the pressure, be

sufficient to produce inflammation in the proper coats of the artery, without their passing immediately into a state of mortification from a want of vitality. If this degree of pressure be too small, the artery does not inflame sufficiently, and is not obliterated, but is rather wasted slowly and then bursts: if the pressure is too great, and especially upon an artery insulated in a greater space than is required for the ligature, it mortifies, ulcerates, and opens before the sides of it have adhered to each other, both at the place of the ligature, and for a certain space above and below it.

Both of these accidents may be avoided, by separating with the point of the finger, and insulating the artery from the cellular substance, in that portion only corresponding to the space which the ligature ought to occupy, which space is a little more than four lines. In stripping the artery in that part of its cellular sheath, it is to be done so that the ligature falls on the proper coats of the artery only, so that the surgeon can calculate with precision the degree of pressure which he ought to employ for keeping the two opposite sides of the artery in mutual and firm contact, without danger of being lacerated by the tapes or thrown into mortification. The Arabian physicians, as I shall shew in another place, were very careful in the performance of this important article of practice, relative to the ligature of the great arteries of the extremities; for they invariably before tying one of these arteries, not only laid it bare accurately for a certain space, but likewise, that the ligature which they applied might not include other parts than the denuded artery, they lifted up the artery with a blunt hook. The two waxed tapes which I propose to employ, placed contiguous to each other, each of which is two inches in breadth, rest upon a convenient space of denuded artery, on which account they can with difficulty produce its division. As the ligatures are only tightened upon the artery by the intervention of a cylinder of linen placed on the artery lengthwise, and as the transverse diameter of this cylinder projects a little beyond the sides of the artery, it therefore follows, that when the knot is conveniently tightened, the sort of ligature formed by it is not, as commonly happens, a circular strangling, or puckering of the proper coats of the artery, but, properly speaking, an approximation of the two opposite sides of the artery for the space of four lines, or as if the artery in all that space were kept compressed and held between the points of the two fingers. This, in my opinion, is the best mode the surgeon can take to prevent the rupture of the coats of a great artery, and to hinder their too rapid mortification,

to excite in them a due degree of adhesive inflammation, to promote the union and obliteration of the cavity of the artery, and thereby remove the danger of *secondary* hæmorrhage. Mr. *Burchall*,* in tying the *superficial* femoral artery circularly, as is generally practised, exposed the patient a few days after to a most dreadful secondary hæmorrhage. He immediately passed a second ligature above the first, he inserted between the artery and the knot, a cylinder of plaster, and then not a single drop of blood appeared during the whole time of the cure.

Mr. Thompson *Forster*,† besides the small compress or cylinder of linen, wished that over this there should be placed lengthwise a segment of a cylinder of wood, three quarters of an inch in length, and a third of an inch in breadth: but experience has convinced me, that the cylinder of linen alone answers the intention perfectly well. It is a constant fact, that the ligature applied in this manner, or by the interposition of a cylinder of linen, is much longer of being detached from the artery, than the ligature performed in the common way. * * * * * * *

* * * If, as I have said above, to avoid secondary hæmorrhage, it is necessary that the *ulcerative* process of the artery at the place of the pressure caused by the ligature happen after the adhesive process is perfectly completed, it is evident that the first mode of ligature, as that which is longer of coming away from the artery, will favour more than the other the perfect adhesion and obliteration of the artery, and will, therefore, more effectually remove the danger of secondary hæmorrhage. This mode of preventing *secondary* hæmorrhage, it is proper to remark, is not at all new. The interposition of a small compress between the artery and the ligature, before drawing the knot, was practised by the ancient, particularly the Italian, surgeons. They have all taught this precept relative to the ligature of arteries, particularly of a large size, and I do not know why so judicious and useful a practice has been abandoned. *Heister* ‡ even speaks of it diffusely. *Bertrandi* also mentions it in his Trat. delle Operazioni, t. iii. p. 195. And, in my opinion, it is incomprehensible why M. *Deschamps* should regard this practice as useless and hurtful, while he found it convenient and useful to interpose, between the ligature and the artery to be tied, the metallic plate of his *presse-artere*." Scarpa. Wishart, p. 290.

* Medical Obser. and Inquires. vol. iii. p. 108. † Med. Facts and Observ. vol. v. p. 6.

‡ Institut. Chirurg. t. i. p. 269.

Mr. *Hodgson* on this subject says :

" Secondary hæmorrhage occurs at two periods after the application of a ligature to an artery—either within a few hours of the operation, or between the sixth and thirteenth day, when the ligature may be expected to be detached from the vessel. The cause of the first occurrence is the slipping off of the ligature from the end of the vessel, and of course it can only take place when the artery has been divided. The obstacle which that portion of the internal and middle coats situated beyond the division made in them by the ligature must afford to its slipping off, when the ligature is properly applied, will in most instances be sufficient to resist this accident. But if, through a false fear of cutting through all the coats of the vessel, the ligature be not drawn sufficiently tight, or if it be too thick, or irregularly applied, it is evident that the retraction of the vessel may cause its removal. The knots with which a ligature is tied, are often such, that even when the second has been made they are still capable of being drawn tighter. If the ring is capable of being diminished by drawing the ends of the ligature, it is capable of being enlarged by their slipping in an opposite direction : hence the force of the circulation at the end of the vessel, may distend the ring of the ligature from within, and render it so loose as to slip off.

But secondary hæmorrhage generally occurs at a more remote period, namely, when the ligature may be expected to separate from the artery. The principle causes of this accident are the obstacles which the adhesive inflammation has met with in consequence of—1. A morbid condition of the coats of the artery: 2. The application of an improper ligature: 3. Its premature removal: and 4. By sloughing or ulceration of the vessel and surrounding parts.

1. When a ligature is applied to an artery the internal coat of which has undergone a steatomatous thickening, or contains a deposition of atheromatous or calcareous matter, instead of producing an effusion of lymph, and the adhesion of the extremity of the tube, the inflammation is liable to terminate in ulceration and gangrene. Although the internal coat of an artery is extremely prone to the adhesive inflammation, still when those morbid changes which I have mentioned have taken place, ulceration sometimes occurs. Under these circumstances the ulceration from within will in some instances penetrate the sides of the vessel : in other instances, upon the

separation of the ligature, the extremity of the tube will remain pervious and hæmorrhage will be the consequence.

2. It is well known that the adhesive inflammation takes place more readily in clean and simple wounds, than in those that are attended with contusion and laceration: hence a ligature should be employed of such a shape as will effect a simple division of the internal and middle coats of the artery. It is desirable also that their coats should be divided throughout the whole extent of the circle, in order to produce a sufficient effusion of lymph from their cut edges to insure the complete adhesion of the tube. Dr. *Jones* found that the adhesion was not complete where the coats of the vessel were but partially divided; hence arises the propriety of employing such a ligature as shall effect their entire separation. A broad ligature does not make a smooth and even wound in the coats of an artery; and in consequence of its extension beyond the point of adhesion, the subsequent ulceration which is necessary for its detachment may expose the cavity of the artery above the place of its union. Flat ligatures, such as pieces of tape &c. will effect only a partial and contused laceration of the internal coats, and like the broad ligature, by extending beyond the point of adhesion and exciting ulceration, will lay open the cavity of the vessel, and give rise to hæmorrhage. From the same reason it is evident how opposite to the processes of obliteration is the employment of gradual or extended pressure, which, instead of operating upon the internal coats of the artery, produces ulceration from without, and exposes the cavity of the vessel. Hence also the impropriety of surrounding the artery with cylinders of linen, plates of cork or wood, slices of agaric, *serre-arteres*, *presse-arteres*, *ligatures d'attente*, and a variety of inventions which have been employed for the purpose of preventing, but which in fact tend to produce secondary hæmorrhage. The surrounding parts included in a ligature with an artery, generally slough or ulcerate: if these effects extend to the coats of the vessel, its cavity will be liable to be exposed, and hæmorrhage to ensue.

3. The importance of absolute quietude in promoting the adhesion of wounds in general, indicates the necessity of its observance after the ligature of an artery. The facility with which recently cicatrized surfaces are torn asunder, proves how readily the slender point of adhesion at the extremity of a tied artery may be separated by the exertions of the patient. Improper attempts to expedite the detachment of the

ligature, by twisting it, or pulling its extremities, may cause its removal before the adhesion at the end of the vessel is sufficiently firm to resist the impulse of the circulating blood, or the violence employed may destroy the union.

4. The most frequent cause of secondary hæmorrhage is the ulceration or sloughing of the extremity of the artery, whereby its cavity is exposed above the point of its obliteration by the ligature. This accident is generally produced either by the sloughing or ulceration of the vessel in conjunction with the surrounding parts, or by the occurrence of those conditions in the artery alone, in consequence of the employment of improper contrivances to effect its obliteration, or of improper modes of treating the wound. All those causes which excite ulceration or sloughing of wounds in general, will be liable to produce these effects after the operation for aneurism." HODGSON on Arteries and Veins, p. 201, &c.

Mr. *Travers* speaking of secondary hæmorrhage, says: "The causes which I have enumerated are three fold.

1. Failure of the adhesive inflammation.
2. Diffused and extending ulceration.
3. Sloughing or gangrenous inflammation." MED. CH. TRANS. vol. iv. p. 456.

APPENDIX M.—Page 91.

On the Temporary Ligature.

"IT has been proposed to take away the ligature with which an artery has been tied, before the usual time has elapsed which is necessary for its natural separation, providing it can be done without interfering with the success of the operation. It is now thirty years since experiments were commenced upon this subject in England. *Jones* states, that having cut through the internal and middle coats of an artery in three or four points, with an equal number of ligatures, an effusion of lymph has been

produced sufficient to produce the required obliteration, and admitting the withdrawal of the threads after the lapse of a few minutes. The results of *Hutchinson's* experiments fully confirmed this assertion. But *Dalrymple*, *Hodgson*, and *Travers* have been less fortunate: in the experiments which they performed upon horses and sheep, obliteration never followed the attempt: upon examination after thirteen, fifteen, or eighteen days, the artery having merely undergone some contraction. *Travers*, however, thought that great advantage might be derived by modifying the suggestion: instead, therefore, of taking away the ligature at an early period, after having applied it upon the artery, he determined to allow it to remain for a considerable length of time until the coagulum and effused lymph had acquired a certain degree of firmness, a consistency capable of withstanding the impulsion of the blood. From the attempts which he made upon horses he drew the following conclusion; *that the ordinary consequence of maintaining the application of a ligature upon the carotid artery, for a period of six, two, or even one hour, is a permanent obliteration of the vessel.* In 1817 he applied a ligature upon the brachial artery of a man, and when it was taken away fifty hours afterwards, pulsation in the tumour did not return: *Roberts* has succeeded to a still greater degree: a ligature which was applied to the femoral artery of a sailor, for an aneurism in the ham, for twenty-four hours only, was found to effect a complete cure in twelve days.

A repetition of these experiments, have untortunately not always obtained the same success. *Hutchinson* has seen the circulation re-established immediately in the femoral artery, although a ligature had been firmly applied for six hours. Sir Astley *Cooper* has observed the same circumstance after a period of thirty-two or forty hours. *Travers* himself, in withdrawing the ligature which had been applied upon a femoral artery for twenty-five hours, has seen the pulsations gradually return in the aneurismal tumour, which did not yield to mediate compression continued for a considerable length of time, and ultimately required the application of a ligature after the usual method: he has therefore renounced the practice, and the experiments which *Beclard* has instituted have prevented its adoption in France.

At the same time when, in London, the temporary ligature lost its strongest supporters, the Italian surgeons were defending its use. *Scarpa* instituted new experiments and attempted to establish its employment as a principle. Flat ligatures,

tied upon a small cylinder of cloth covered with cerate, applied around the carotid artery of several sheep, and withdrawn on the third, fourth, or fifth day, have invariably effected a solid obliteration of the vessel: and when these experiments were repeated by M. *Mislei* the veterinary surgeon at l' ecole de Milan, exactly the same results were procured. In the human subject, success has not been less great. *Paletta* communicated to *Scarpa* two remarkable instances of this kind. The first occurred in a man forty years of age, who had an aneurismal tumour in the ham for two or three months. A ligature was applied upon the femoral artery, January 8th, 1817, and withdrawn on the 12th. The second in an individual of 60 years of age, having an aneurism in the bend of the arm. A ligature placed on the humeral artery, was taken away on the fourth day; and, as in the former case, the termination was favourable. A popliteal aneurism was operated upon in the same way, with equal success. In a fourth case also, when the humeral artery was opened, in a patient, in the Hospital at Paria, the same occurred. M. M. *Molina, Fenini, Maunoir, Wattman, Fitz, Medora, Solera, Roberts, Falcieri, Uccelli, Giuntini,* and *Malago,* have used the temporary ligature with success, in aneurismal tumours of the carotid and femoral arteries, etc. *Vacca* makes the objection, that after having taken the ligature away, the section of the artery is not the less effected, soon or late: and the experiments of *Pecot,* in opposition to those of *Seiler,* go to prove this opinion, which in other respects do not invalidate the facts and rationale which *Scarpa* has advanced." VELPEAU, tom. i. p. 85.

On this subject, in "*Observations upon the Ligature of Arteries*" by *Travers,* we find the following.

"*Jones,* whose scientific and comprehensive view of this important branch of surgery, must excite universal regret for his loss, and respect for his memory, ascertained, that the effusion of lymph from the wound inflicted by the ligature was sufficient, even if the ligature was removed upon the instant, to obstruct the artery. By including a loose thread along with the artery in the ligature, he readily withdrew the latter after the infliction of the wound. In one instance he succeeded with a single ligature, and in several instances with two, three, or four, made at a small distance apart. The lymph effused was in proportion to the extent of the section, or if this was incomplete, the union was equally so. He was led to conclude that the complete

circular section of the internal coat was indispensable to union, and the success which attended his experiments led him to conjecture, that in some surgical cases removing the ligature as soon as it was made would be an efficient operation. This suggestion, the value of which he left to be determined by future experimenters, was caught at with eagerness by his readers, and by many considered to be the essence of his publication. It required little sagacity to discover the advantages which would result to practice, if it could be shewn that the effect of the ligature which heretofore required fifteen or twenty days, could be attained with equal certainty in little more than as many seconds. But just as was this suggestion in theory it was not yet realized in practice, and the fact was chiefly valuable as it afforded conclusive evidence of the principle which he had established, viz. that the obliteration of an artery was effected by the adhesive inflammation.

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It appears to me that the residence of the ligature on the artery stamps an imperfection on the operation of an aneurism, which the facts ascertained by experiment plainly indicate to be remediable. Such is the rapidity of the union by adhesive inflammation, that lymph is in a state favourable for organization in less than six hours in a wound, the sides of which are preserved in contact. And long previous to the appearance of that coagulable lymph which is the medium for the inosculation of vessels, a glutinous exudation from the cut surfaces fastens them together. In my experiments on the intestines of dogs I had many proofs of this, and the same thing has been observed in wounds of other parts. But would the pared edges of a hare lip unite by adhesion, favourably as they are disposed to union when brought in contact, if they were allowed to remain asunder? Certainly not. It occurred to me, therefore, that if a round ligature were applied and suffered to remain upon the vessel for a few hours, it would have fulfilled the intention of its application, and by its removal at this period the dangers and inconveniences attending its stay would be obviated. Suppuration which chiefly results from the irritation of the extraneous body, was never observed in less than twenty-four hours, and very seldom so soon: and although the ulcerative absorption, which sets the ligature free, commences at the period of suppuration, it is never finished in less than eight, seldom in less than fifteen, and often not in twenty

days. Now if the opposite lips of the wound in the artery were kept in contact for a time sufficient to ensure their adhesion, suppuration and ulceration of the external coat of the artery would probably never ensue; the artery would be obliterated without losing continuity, and the wound would heal like a simple wound by the first intention. This reasoning seemed to me plausible enough to justify an experiment or two: I made them, and the following is the report."

After detailing the experiments, he proceeds:

"That the coaptation of the wounded surfaces of the cuticular coat of an artery, if preserved for a short period after the infliction of the wound, renders its obliteration certain, is a fair inference from these experiments. A more extended scale of inquiry, however, is required to establish the uniformity of their results. They afforded evidence that the circulation was arrested, by the absence of the pulse in the artery continuing after the removal of the ligature: and the vessel was therefore concluded to be as impervious as if the ligature had remained upon it. But upon this event I think it would be impossible to calculate with confidence, unless the ligature were suffered to remain upon the vessel for a time sufficient to insure the organized adhesion of its sides. In *Jones's* experiments, the return of the circulation was invariably ascertained after the removal of the ligature; and he seems to have regarded this as a proof that the subsequent obliteration of the canal was effected by a process independent of the coagulation of the blood. But in all these and similar experiments, the blood, as blood, has no concern in the obliteration of the vessel: the conical coagulum of blood is not formed in the first stage of the obstruction; its formation is gradual, and appears to require a change in the properties of the vessel consequent upon the abolition of its function. And although the presence of the conical clot satisfactorily demonstrates the obstruction of the canal, it is sometimes very inconsiderable, and at other times deficient, where the obstruction is complete. It is a mistake, therefore, to regard the coagulm of blood among the immediate effects of the ligature; it is an incidental consequence only of the permanent obstruction which it has been supposed to constitute; without which it never could be formed, nor, if formed, ever be competent to the purpose of permanently obstructing the canal of an artery." MED. CHIR. TRANS. vol. iv. p. 441, 460, &c.

In a paper communicated two years afterwards, Mr. *Travers* says:

"It is now well known, that the result of tying an artery, and removing the ligature instantly, is a wound or fissure of the middle and internal coats, which is soon occupied by lymph and gradually obliterated by cicatrization, the vessel remaining pervious. But if three or four ligatures are applied contiguous to each other, forming as many distinct fissures, the lymph is effused in such abundance as to project into the cylinder, and obstruct the passage of the blood.

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The obstruction of an artery may, I believe, be regarded as an invariable consequence of the application of a ligature for six hours, in the species of animals which were the subjects of these experiments. It is an indispensable condition, however, that the mode of applying the ligature be such as to insure the division of the inner tunics, a condition which it will be more difficult to prevent, than to execute, if the ligature be of a proper form."

He draws the following conclusions from his experiments:

1. "No material obstruction is opposed to the passage of blood upon removing the ligature at a period of six or even of nine hours from its application, and consequently its ultimate obstruction under these circumstances must be referable to the gradual completion of the adhesive process.

2. The residence of the ligature for a period of six hours, affords direct evidence of an inflammatory action in the deposition of lymph between the divided tunics: which deposition is more abundant at nine hours, and sufficient for the obstruction of the vessel in twelve; presenting the form of an interstitial cord between the lips of the fissure, and continuous with it, a membranous septum extending across the vessel.*

3. The septum of lymph is formed prior to the coagulum of blood, and in all cases of ordinary circulation is, of itself, adequate to the prevention of hæmorrhage: but under a sudden extraordinary impulse of circulation, or a violent concussion *ab externo*, is liable to be ruptured and give passage to the blood. If, however, an interval of six hours be suffered to elapse after the removal of the ligature, the same violence is not followed by hæmorrhage, although no coagulum of blood be formed.

* This septum is concealed by the cylindrical coagula of blood which adhere to it intimately.

4. The cylindrical coagulum of blood supporting the septum of lymph is an additional preventative to hæmorrhage, under extraordinary impulses. It may be formed at twelve, or may not be formed at twenty-four hours; the nearest collateral branch being equally distant, and the obstruction equally complete in both cases.

5. A period of twelve hours is sufficient for the obstruction of the vessel by lymph, so as to admit of the removal of the ligature, and the wound or division of the artery without danger of hæmorrhage.

6. The addition of the pressure of the ligature to the wound which it inflicts, accelerates the adhesive process; thus, within a certain limit, the earlier the removal of the ligature, the more remote is the period of obstruction. If applied for six hours, it is unsafe to open the artery in less than twenty-four hours; if for twelve hours, the artery may be opened immediately.

7. The ligature applied for twelve hours upon the truncated artery, is equally safe as upon that which is continuous.

8. The coagulum of blood is larger and more extensive in the truncated than in the continuous artery, and is not bounded by collateral vessels, but extends into them; probably owing to the feebler propagations of the heart's impulse along the divided and retracted vessel, and the consquently greater quiescence of the fluid blood." MED. CHIR. TRANS. vol. vi. p. 641, &c.

APPENDIX N.—Page 91.

On the Nature and Form of Ligatures, and their relative value.

"UNTIL the present century no ligatures were used by our surgeons except such as were made of linen or flax; a single or round thread being preferred for the small arteries: whilst for the large trunks, on the contrary, several were united together by waxing them, so as to form a tape. It happens, however, that the ancients were in the habit of employing silk for this purpose: *Guy de Chauliac* asserts this positively.—

Such was the practice adopted when *Scarpa* and *Jones* determined to submit the method which had been followed as a matter of mere routine to the test of experiment and rational deduction.

The former of these authors stated, that to effect an obliteration of an artery, its parietes must be placed in contact, without producing any rupture, and that adhesive inflammation must be excited. *Scarpa*, therefore, proposed the use of two broad ligatures, formed of thread having six twists, and in addition, he recommended that a small cylinder of cloth, six lines long and three broad, should be placed between the ligature and the artery: this kind of pad was adopted by *Para*, *Platner*, and *Heister*, and by nearly the whole of the Italian surgeons of the last century, by *Funchall*, by *Forster*, who proposed to substitute a small cylinder made of wood, a quarter of an inch broad and three quarters long: it is mentioned by *Saviard* as being in general use in his day, and a piece of cork has been since substituted for it by *Cline*. By this plan the internal and middle tunics are neither bruised nor torn: their contact is perfect, their union firm, and they are even agglutinated before the tape which surrounds them, and which with difficulty produces ulceration, can possibly be separated.

According to *Jones*, this opinion is altogether erroneous: the artery not being closed by the inflammation of its internal surface, but rather by the effusion of the concreting or organizable substances which are poured out after the section of the middle and internal tunics: therefore, in place of the broad and flat ligatures, the pads of linen, or cylinders of any other substance, which prevent this section more or less, he, on the contrary, advocates the employment of such threads as effect it in the cleanest and most easy manner. He has made numerous experiments upon dogs and horses, and the whole have given results favourable to his theory, which was soon received by the English surgeons as a principle of practice.

According to *Hodgson* the truth of the hypothesis is so evident, that he cannot understand how any one can continue to use the broad ligatures and small pads recommended by *Scarpa:* and it is not without some severity, that Mr. S. *Cooper* censures the French surgeons for adopting, with so little readiness, the practice which *Jones* recommends: a practice which has induced some of his countrymen to prefer the smallest threads possible, silk threads and such as are made of dentist's or fisherman's silk, threads in fact so small that when they are cut near the knot, as proposed

by *Lawrence*, only a 20th or even 46th part of a grain remains in the wound. Without denying the importance of the labours of *Jones*, M. *Roux* has continued and still maintains the use of broad ligatures, which he usually ties upon a small pad of diachylon. In support of this plan, must be added the practice of *Boyer*, *Scarpa*, and even of the ancients, since *Saviard* mentions in his Surgical Observations, the use of the cylinder as a common occurrence. *Crampton*, of Ireland, has never adopted any other, and has had no reason to lament his choice: and he has even contended so powerfully against the doctrine of *Jones*, that he has prevented its implicit adoption in Britain. M. *Richerand* has endeavoured to reconcile these conflicting opinions by suggesting that a broad ligature when it is tightened becomes rounded, and that it ultimately occasions, like the round ligature, the rupture of the middle and internal coats of the vessel: this supposition tends to the justification of the opinions entertained on this subject by the British surgeons. But here must be noticed the assertions of *Jameson*, of Baltimore in America, who after instituting a series of new experiments, denies the correctness of the principal assertions of *Jones*. It is not true, he says, that the rupture of the fragile tunics of an artery is advantageous: it must, on the contrary, be avoided: small threads, round ligatures, are dangerous, both because they divide the internal and middle tunics, and especially, because they destroy the *vasa vasorum* of the cellular membrane. He, moreover, forbids the placing of any foreign substance whatever between the vessel and ligature; as well as the thread ligatures, of all sizes and forms: narrow strips of untanned deer skin appear to him to be infinitely preferable in all cases, because they possess an elasticity and suppleness which produce the closure, and the easy folding of the vessel without any accompanying rupture, without the laceration of the *vasa vasorum*, and may be left in the wound with impunity.

From this difference of opinion another question arises. It has been asked, if it is not possible to substitute for the threads of vegetable, others made of animal substances, capable of being softened and dissolved, and which might thus be taken away by the process of interstitial absorption from the midst of the living tissues, and without preventing, to any extent, the immediate union of the divided parts. Several attempts of this nature have been made in 1815, in London, with silk: those by *Lawrence*, and others by *Cawardine*, have met with the desired success: adhesion of the wound has taken place in four, five, or six days, and the small knot left upon the artery, did not

give rise to any accident. Other individuals have been less successful, either the immediate union has failed, or at an after period, small purulent collections have formed, or small abscesses which are only healed after the expulsion and evacuation of those portions of the silk which had been left in the tissues. In a patient upon whom an operation was performed on the 29th March, 1819, by Mr. *Lawrence* himself, the wound was not entirely healed until the end of May. In a case observed by Mr. *Watson*, in which the humeral artery had been tied on this principle, the knot of the silk opened the cicatrix and did not escape until the end of two months. A similar circumstance was observed by *Hodgson* after a period of six months: and Mr. *Cummins* mentions a patient in whom the ligature was retained two or three years: so that, in fact, it does not appear that it is possible to effect the absorption of silk.

Sir Astley *Cooper* has completely succeeded by using a ligature of cat-gut: this substance dissolves much more easily than silk, and would be in all respects preferable, if, in consequence of its little resistance, it did not require to be of a considerable size. In the first patient, the healing was completed on the twentieth day; in the second, who was eighty years of age, the wound was cicatrized in four days, and in both instances the ligature never re-appeared. Mr. *Norman* has not met with the same success. This gentleman has twice attempted *Cooper's* plan, and in both instances the healing of the parts has been delayed. In some cases which were operated upon according to *Bransdor's* method, *Wardrop* has used the intestine of the silk worm in the form of a thread.

According to the statements of *Jameson* and *Dirsey*, *Physick* of Philadelphia, was the first who used ligatures formed of animal matter in 1814: those which he prefers are round and made of deer's skin or cat-gut; but he wished, with *Lawrence* and *Cooper*, to rupture the arterial tunics, whilst *Jameson* was anxious to keep them perfect.

The breadth of the ligature which *Jameson* uses is about two lines, and he increases their capability of resistance and firmness more or less by drawing them between his fingers: when they are applied upon an artery, it is not necessary in obliterating its cavity to tighten them considerably: and it hence happens, that notwithstanding the absence of any intermediate foreign body, they produce the same effects as ligatures which are applied according to *Scarpa's* method, without arresting, like the latter, the circulation in the vascular system of the cellular tunic. *Jameson* asserts that after

they have been drawn through the fingers, these ligatures may, when considerably tightened, partially cut the arterial tunics like the flat ligature made of linen or silk. Whilst in their natural state of suppleness, they are incapable of producing this effect.

Levert of Alabama, in America, announces, however, results of another kind. Having noticed that lead, gold, silver, and platinum irritate to a small degree only, the parts with which they are in contact, *Physick* first suggested the idea of forming ligatures of these metals. *Levert* performed a very considerable number of experiments in proof of the accuracy of this suggestion: he tied the carotid artery of a dog in five situations with a leaden ligature, and having cut off the loose ends near the knot, he left it within the wound. Immediate union has followed at the end of the seventh, eighteenth, nineteenth, twenty-eighth, and forty-second days: the vessel was invariably found to be obliterated, and the small circle of lead, inclosed in a cellular cyst of variable density. Three experiments upon the carotid, and two upon the femoral with a thread of gold, three other ligatures upon the femoral and the two carotids with threads of silver, and three upon the carotid with platinum, have given exactly the same consequences with those procured from the use of the leaden ligature: and lastly, the same results have been obtained from ligatures of waxed silk, of elastic gum, and even of grass.

From all these experiments, the consequence is, as appears to me, that the nature and figure of the ligatures employed in the treatment of aneurisms, are by no means so important as, for the last thirty years, it has been generally supposed, and that the French surgeons have been justified in not hastily or implicitly adopting the deductions which have been drawn in England from the experiments of *Jones*. The large ligatures recommended by *Scarpa* irritate the wound too much, maintain a two abundant degree of suppuration, and can only be withdrawn at the termination of a considerable length of time, to deserve any exclusive preference: this appears to me, to be incontrovertible; but whilst they flatten the artery without puckering it, they keep its parietes in perfect contact, without necessarily cutting the *vasa vasorum*. When the cellular tunic is inflamed under an equal pressure, it soon transmits its organization to the two other arterial membranes, and the whole are in a short time confounded together so as to form an impermeable cord. The objections, therefore, which *Hodgson* has urged against them are by no means strictly founded. When a small ligature is

used, more effectually to rupture the internal and middle tunics, in *Jameson's* opinion they strangulate the small vessels of the external membrane; and obliteration is not especially produced by the internal effusion of the organizable lymph as *Jones* imagined; on the contrary, the ligature itself is rapidly surrounded with concreting matter: the continuity of the ruptured small vessels is soon re-established upon the external surface, and it terminates in being found in the centre of an organic ferule analogous to that which *Duhamel* believed to occur in the formation of callus in a fractured bone. This albuminous formation, the mechanism of which M. *Pecot* has carefully examined in dogs, gradually hardens, contracts, and is lost with the two obliterated ends of the artery, when the ligature is extracted. M. M. *Scarpa*, *Crampton*, and *Jameson*, have therefore erred, in attributing to the small ligature, a much greater tendency to produce secondary hæmorrhage, than those which are broad and large.

It cannot be doubted, when speaking of the ligatures formed of animal substances, that, by permitting an immediate closure of the wound, they afford valuable assistance in practice. Their form and precise nature remains to be ascertained. If it is wished that they should be very small, silk alone may be employed: unfortunately we have seen that the interstitial absorption of the organs does not act upon them.—Cat-gut does not possess an equal degree of firmness, and is absorbed with equal difficulty.

The strips of deer's skin which are easily dissolved, and possessing great elasticity, offer greater advantages: but before the surgeon can avail himself of them, additional experiments must be performed, that the results obtained by *Jameson* may be confirmed by others. In admitting that if the ligatures are left around the artery they do not irritate like foreign bodies, that the organism can take them up, and that it is not necessary that they shall be expelled at one time or other, every one must in a moment see the important services which they hold out for the patient. With them the plastic ring pointed out by *Pecot* would be complete and protected from every perforation and every interruption: being supported by the exact approximation and direct union of the parts, no risk is incurred of its being destroyed by suppuration, or ruptured by the escape of the ligature. Moreover, whether the ligature be a little greater or a little less, whether the internal and middle tunics are or are not ruptured, whether the *vasa vasorum* are much or little constricted, I believe that the ultimate result will not be the less nearly alike." VELPEAU, tom. 1. p. 80, &c.

Appendix O.—Page 99.

On Alterations of Structure in Arteries.

"There is another morbid secretion which is still more frequently found than pus under the internal coat of arteries: I allude to that peculiar substance which has long been described under the name of *atheromatous* matter. It has the consistence of suet, feels greasy to the touch, and when broken down under the finger gives the sensation of minute gritty points, thinly scattered through a fatty substance. In other cases the saline matter is more abundant, and exceeds, in quantity, the fatty substance, or is even found without any of that substance, in which case it forms one or more hard concretions, that have a much stronger resemblance to mortar than to bone. These concretions present considerable variety in their physical properties, and, as they constitute one of the most frequent alterations to which the arteries are liable, I shall enter somewhat minutely into the history of their developement.

Calcareous concretions are so constantly found in the arteries at an advanced period of life, that *Bichat* computed that out of ten persons over sixty years of age, seven would be found with these concretions. According to *Baillie*, it is more common to find the arteries ossified than not, in old age.* Neither are the other periods of life exempt from this affection: thus *Young* found the temporal artery ossified in an infant of fifteen months, and Doctor *Wilson* saw the aorta ossified at the age of three years. I myself observed several ossiform plates in the aorta of a littte girl only eight years old, and I have seen five or six instances of similar appearances in persons of from eighteen to twenty-four years of age: lastly, I found an extensive ossification of the superior mesenteric in an individual not quite thirty.

I do not know of any instance of the internal membrane having been the seat of these calcareous concretions; but it is often detached from its connexions by them. We have already seen that the middle or fibrous coat sometimes undergoes a true

* There are, however, some individuals who arrive at an extreme old age without their arteries becoming ossified, as I have myself ascertained by dissection.

osseous transformation, but that case should not be confounded with this which we are at present considering, where the bony matter is simply deposited between the internal and middle coats. The matter thus deposited originates either in the atheromatous matter already described, which it sometimes seems to take place of, just as calcareous concretions in the lungs take the place of tubercles: or in those white patches, the nature of which is as yet unknown, but which are apparently formed by a deposition of albuminous matter between the inner and middle coats: or, lastly, in cartilaginous patches, which seem only a more advanced stage of the preceding.

At the same time that these calcareous depositions are forming, the middle or fibrous coat undergoes the same alterations as occur in every tissue where a process of morbid secretion is going forward. In some cases, it becomes hypertrophied, and so contributes in part to the considerable thickening which the parietes of the artery in such cases not unfrequently present: in others, it becomes atrophied, and the place which it occupied is taken up by the newly formed calcareous concretion. This latter case, namely, the deposition of bony matter accompanied by atrophy of an adjacent membrane, has in this, as in other instances, been often mistaken for the transformation of that membrane into bone." ANDRAL. PATHOL. ANAT. vol. ii. p. 391.

"A whitish or yellowish exudation is usually the first observable change, which afterwards becomes a patch projecting inwardly. As it increases in size and thickness, it assumes something of the appearance of cartilage, but it is softer in its consistence, and only bears to it a general resemblance in structure. It is the nidus in which calcareous matter is subsequently deposited in numerous small spots, which, increasing more or less slowly, at last form incrustations of various sizes, sometimes in small spots, sometimes in patches. These prevail in the aorta, but in the smaller arteries the calcareous matter sometimes forms complete rings or circles, proceeding even so far as to render the vessel a perfectly incontractile tube. The cartilaginous deposit is sometimes only covered by the calcareous incrustation, and never assumes the perfect character of cartilage in becoming bone as in other parts of the body. The calcareous matter is often deposited in spots, in which no sign of cartilaginous matter can be perceived. The exudation of a whitish matter, which subsequently becomes cartilaginous, is always found on the internal coat of the artery, and has been said to be deposited on

the external surface of it alone, but never on its inner surface. A close investigation of this disease leads me however to the belief, that there is some inaccuracy in this statement, and that the new matter is deposited in the substance of this thin membrane or coat, which seems more particularly affected by it. * * * * * *

In old people this calcareous deposit has been supposed to affect principally the middle coat, and to be deposited in the course of the circular fibres, constituting a different species of disease. It appears to me to be merely an aggravated state of the same disposition, affecting arteries of the second and lower orders, which begins in the middle coat, and not to merit a separate consideration. The calcareous matter, increasing in quantity, gives rise, through pressure, to the absorption of part of the inner coat, and will then be in contact with the blood: by the attrition of which, portions of it may be broken off, and they have been found floating in it, or even obstructing a small vessel. Calcareous matter is sometimes deposited in considerable quantity on the outer coat of an artery, and not on the others.

The calcareous deposit has been found by Mr. *Brande* to consist of 65,5 of phosphate of lime, 34,5 of animal matter, chiefly albumen, with some traces of gelatine, but without any carbonate of lime. It is destitute of the usual fibrous structure of bone, is deposited irregularly, and resembles the callus of bone rather than bone itself. Wherever it is deposited, it destroys the elasticity of the vessel, and renders the coats so brittle, that a ligature will frequently cut through the external as well as the inner ones. The coats of the artery are however so altered by it, and the change which preceded its deposition, that those healthy actions which take place in a sound artery, for its consolidation, after a ligature has been applied, do not always occur; and when the ligature is separated, the artery is found pervious, and hæmorrhage is the consequence. It was principally from the consideration of this circumstance, that Mr. *Hunter* was induced to place his ligature, in aneurism, considerably higher upon the artery than the tumour, with the hope of finding it there in a sounder state.

The obstacles which the calcareous deposit offers to the free passage of the blood through the vessel, deprived in a great degree of its elasticity, leads also to the absorption of the inner membrane, the removal of a portion of the calcareous matter, and often to the formation of a small cavity with irregular edges, which may

degenerate into an ulcer extending to the middle coat of the artery, which has been greatly thinned, if not altogether removed. * * * * * * *

* * The coats of arteries are subjected to other depositions between them, and which have been denominated, from their substance and appearance, atheromatous or steatomatous: although the distinction between these terms, as applied to diseases of arteries, is by no means well defined, or satisfactorily understood. The atheromatous or pulpy spot is more commonly found in connexion with a thickened state of the middle coats of the artery, and is frequently accompanied by calcareous deposition. In some cases these spots have been traced from the purulent state by successive changes into the soft pultaceous matter, which is denominated atheroma; sometimes it is a matter like that which is pressed out of scrofulous abscesses; it is often of a more opaque kind, and occasionally resembling cheese. The atheromatous patches sometimes pervade the whole surface of an artery, and are conjoined more frequently with calcareous than other matter, and a thin layer of this earthy deposit is frequently perceived on their surface. These patches are often found to yield by ulceration, by which the internal coat is destroyed, or is torn by the impulse of the blood. Where several of these patches exist one or more have been found perforating the external coat by extension of ulceration and destroying the patient by hæmorrhage into the pericardium, trachea, or other parts.

I have said that the internal and middle coats of the artery may be, indiscriminately or conjointly, the primary seat of the cartilaginous calcareous deposit. The atheromatous deposit seems principally to be dependent on disease of the internal surface of the fibrous or middle coat, although both the internal and external, sooner or later, partake of it. When the disease has made some progress, the coats of the artery will be found to be thickened generally: and when divided longitudinally into two parts, or slit open, the coats will be seen to be separated by a secretion or deposit which is evidently covered by the inner coat, and which appears to have been formed by the middle coat, and deposited between it and the internal one. A stage further, and the middle coat seems to have been removed, although the quantity of matter may not be greater. By this time, the inner coat has become diseased; in some parts there may be thin scales of calcareous matter, in others, the inner coat may be even ruptured or removed, whilst the outer coat of the artery has been in places so exceedingly thin as to show that a rupture was on the eve of taking place." GUTHRIE, p. 22, &c.

Appendix P.—Page 103.

On Ligatures of Reserve.

"To remedy these disadvantages, (severe hæmorrhage occasioned by the abstraction of the ligature, &c.) ligatures of reserve have been proposed: *i. e.* threads, which only become useful when the one already placed upon the vessel produces the section of the artery, before obliteration is perfect,—in one word, ligatures of caution. One was carried around the artery without being tied, at a distance of some lines below the principal ligature: a second, composed of two threads, was placed a little above the same part, the inferior portion of which was tied in such manner, as would merely constrict sufficiently to moderate the impulse of the blood against that part of the vessel which it is intended to obliterate: a third, which was also double, was situated still higher, and this like the superior portion of the preceding, was left loose. Upon the supposition that the ligature which was primarily tied upon the vessel, was lost, the first portion of the superior ligatures of reserve were immediately used, and the others in succession, if required for the arresting of any hæmorrhage.

The intention fulfilled by the lower ligature, was merely that of preventing any reflux of blood through the wound. Upon this principle, reasoned and acted, the surgeons A. *Monro*, *Guattani*, *Hunter*, *Desault*, *Deschamps*, *Pelletan*, and for a long period, even *Boyer*. At the present day, ligatures of this nature have almost entirely disappeard from practice. So far from being considered advantageous, they are now regarded as very dangerous, occasioning, in the first place, too considerable irritation of the wound, maintaining the suppurative process, and presenting an inseparable obstacle to immediate union. *Dupuytren* and *Beclard* have shewn that they excite inflammation of the parts, and that the point of the vessel which adjoins becomes lardaceous, very easily divided, and altogether incapable of sustaining the operation of a ligature of any kind: it hence follows, that their mere presence is sufficient to determine the ulceration of the artery; that they divide, moreover, with the same facility that lard or cheese is cut, when they suffer the slightest degree of constriction. Velpeau, tom. i. p. 83.

Appendix Q.—Page 106.

On the spontaneous Cure of Wounds of Arteries.

The following is a brief summary of the different cases in which a spontaneous cure may be effected.

Case 1.—When the wound is simply a punctured one, made by a small instrument, a coagulum forms in it, which though at first it acts merely as a mechanical stopper, subsequently becomes organized, and is transformed into a tissue in every respect similar to the arterial.

Case 2.—When the incision of the artery is parallel to its axis. The same phenomena are observed as in the preceding case.

Case 3.—When the incision of the artery is made transversely to its axis. In this case, very different phenomena result according as the cellular sheath has been removed or not. When it has been removed, as is sometimes done in experiments on animals, the hæmorrhage only ceases with the life of the animal. On the other hand, when the artery has not been denuded of its cellular coat, it arrests the blood in its meshes, and thus favours the formation of a coagulum; the hæmorrhage ceases, and the coagulum in some instances becomes organized, and is transformed into a true arterial tissue: more commonly, however, the coagulum does not become organized, but at the end of a certain time is detached, and a fresh hæmorrhage ensues.

Case 4.—When the artery is perfectly divided, if the cellular sheath has been dissected away, the hæmorrhage which ensues is necessarily fatal: but if the sheath has not been removed, the internal and middle coats retract, so as to leave the cellular coat projecting several lines beyond them: and the meshes of this cellular coat serving to entangle the blood, a coagulum is thus formed, which extends along the interior of the artery as far as the next collateral branch, and eventually, that portion of the vessel is converted into an impermeable cord. Andral. Pathol. Anat. vol. ii. p. 382.

PART III.

OPERATIVE PROCESSES.

Since the publication of the magnificent plates which accompany *Scarpa's* Work on Aneurism, in which the distribution of the arteries, and the extensive and numerous anastomoses which these vessels possess with each other, are demonstrated; and especially, since the many well authenticated facts of Pathological Anatomy, which have been brought before the observation of the scientific, exhibiting the resources which nature derives from these anastomoses to supply the want of an artery of a limb, when it has been obliterated; the surgeons of every country have unhesitatingly practised the ligature of arteries. Nevertheless, it has only been by degrees, and after many attempts considered very hazardous, but crowned with complete success, that we have been enabled to tie the large trunks, near their origin from the aorta, and even to attempt the aorta itself a little above its termination.

It is not, however, our intention in the succeeding part of the work, to

give either the general history of these different operations, or to trace the successive progress of art, during the last quarter of a century, upon this branch of Surgical Therapeutics. We leave this to the care of the writers of elementary treatises upon this subject. Nor do we wish to augment the size of the work, in the description and detail of many facts undoubtedly of the greatest interest, but which are not absolutely practically necessary. We think, however, that a concise account of the indications of the principal ligatures of arteries, with their results, will serve as a guide to young practitioners, and enable them to appreciate the different chances of success which these operations present. But, upon the relations of each artery with the adjoining organs, and the changes which these relations undergo in different points of the course of the same artery, we have been particularly minute.

If, in every surgical operation, a perfect knowledge of the structure of the part upon which it is intended to operate, is necessary; it is in none so requisite, as in that of the ligature of an artery; in this case, it is generally in the midst of organs the most essential to life, such as nerves, arteries, and veins, that the surgeon directs his instruments, so that the least deviation, may wound parts which might cause the instantaneous death of the patient. In all cases, uncertain and difficult manipulations, if they do not cause this fatal accident, are always liable to be followed by secondary hæmorrhages.

The knowledge of relative anatomy is then, the basis upon which to practise the ligature of arteries: it is by this science alone, that surgeons have possessed the self-possession and confidence necessary to the performance of those new operations which have been practised of late years: it is by this guidance that I have proposed and carried into execution new modes of operations; that the ligature of many arteries has already been accomplished; and that, the possibility of tying certain other arteries, hitherto unattempted, may be demonstrated.

Not being able to give more than one view of the ligature of each artery throughout its course, one method only could be represented, of tying each artery upon those points of its course where it can be done: we have not, however, neglected to describe, in the text, many other modes of operation; and hope, by the arrangement of the plates, that the reader will be able easily to follow the description of those operations which are not represented.

Plate III.

Ligature of the Arteria Innominata, (brachio-cephalic trunk,) and of the Subclavian within the first Rib.

A—Superior edge of the sternum.

B—Internal extremity of the clavicle.

C—Inferior extremity of the sternal portion of the left sterno-cleido-mastoid muscle.

D. D. D—The same muscle of the opposite side.

E—The sterno-thyroid muscle.

F—The sterno-hyoid muscle.

G—Anterior scalenus muscle.

H—Trachea, and superior part of the thyroid cartilage.

1—Brachio-cephalic trunk.

2—Primitive carotid artery.

3. 3—Subclavian artery.

4—Common origin in this subject of the ascending cervical, transverse cervical, and superior scapular arteries.

5—Internal jugular vein.

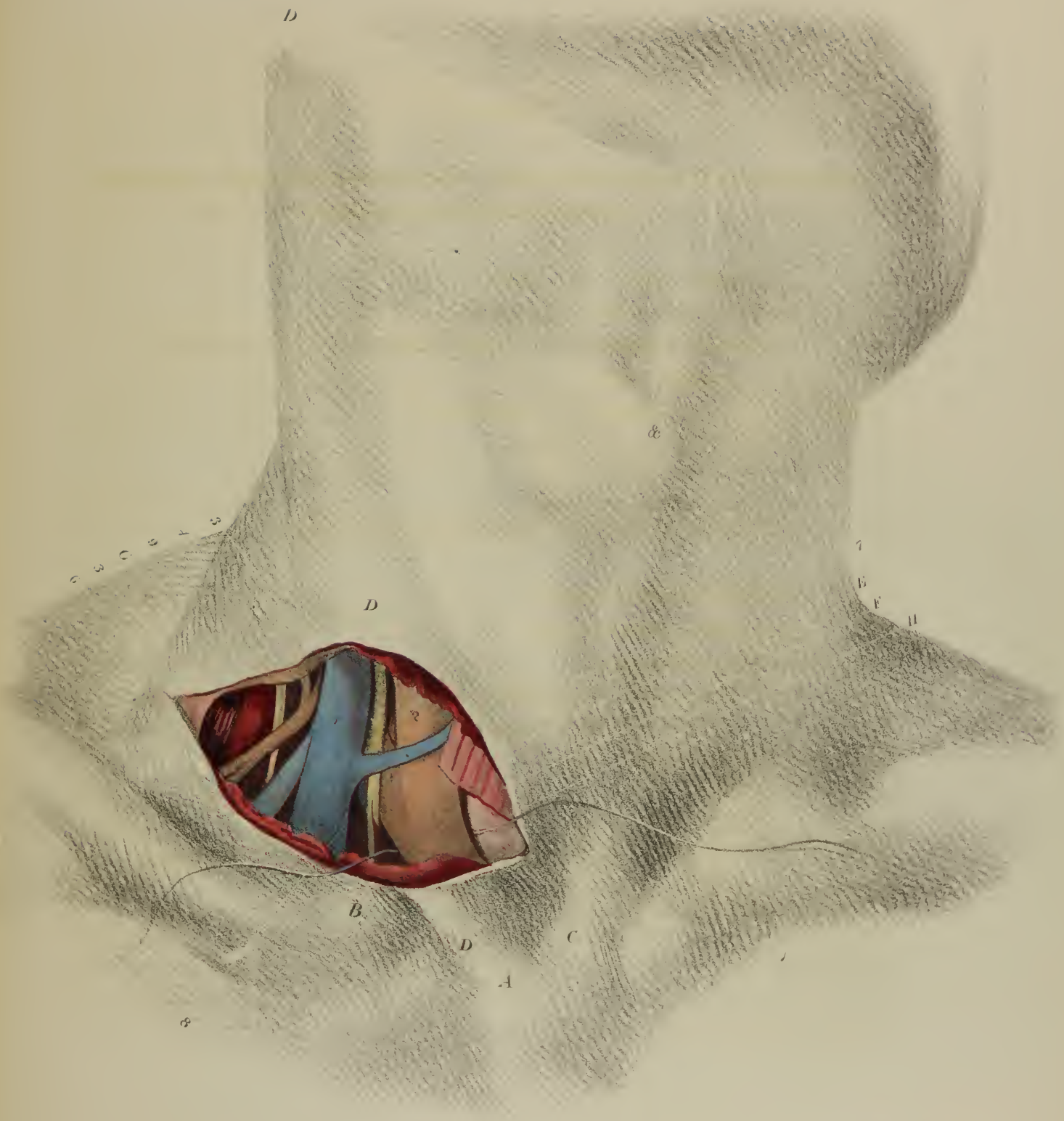
6—Vertebral vein.

7—Thyroid vein.

8—Pneumo-gastric nerve at the point where it furnishes the recurrent nerve.

9—Diaphragmatic nerve.

PL. III.



R. Martin Lithog. 134. High Holborn

I. THE INNOMINATA ARTERY.

The possibility of performing the operation of the ligature of the arteria innominata, has been long and frequently discussed: some, in admitting the operation to be practicable, manually speaking, yet advise its avoidance, fearing the circulation cannot be carried on in the superior extremity, and the situation for tying the vessel being too near its origin is likely to cause hæmorrhage upon the separation of the ligature. Others, without denying the great inconveniences of this operation, or disputing the danger of hæmorrhage upon the detachment of the ligature from the vessel, strongly urge its performance, when there is no other means of saving the life of the patient.

It was under these circumstances that two foreign surgeons performed this operation; the first, M. *Mott*, of Philadelphia, and the second, M. *Graffe*, of Berlin. Although both cases proved fatal, yet as the patients lived some time after the operation, there can be no doubt that the circulation in the thoracic extremity and the corresponding side of the head was maintained. With respect to hæmorrhage, the danger is much greater; no circumstance yet proves that the distance from the point occupied by the ligature, and the origin of the artery, is sufficient for the formation of a coagulum: the length of the arteria innominata, which is from fifteen to eighteen lines, would readily allow the formation of a coagulum, in an artery of middle size, and at a certain distance from the heart; but, here, it is probable that the force and rapidity of the flow of the blood would always oppose its coagulation; and then, there remains no other means of preventing hæmorrhage, but the adhesion of the lips of the divided internal and middle tunics. In my experiments upon animals, this adhesion has only taken place twice out of four times, and yet in them the plasticity of the coagulable lymph and the unctuous matter which lines their arteries, is much greater than in man.

Notwithstanding the small chances of success that this ligature presents, there are cases in which it ought to be applied, but they are very rare. It is difficult, in fact, to suppose any lesions of the origin of the carotid or rather of the right subclavian artery, which can present conditions favourable for this operation; the same may also be said with reference to aneurisms of these two arteries.

The innominata or the brachio-cephalic artery is the first branch given off from the arch of the aorta; it is situated deeply in the summit of the thorax, and at the inferior part of the neck. Sometimes this artery is wanting: in this case the right primitive carotid and the right subclavian arteries arise separately from the aorta. When it exists, its internal side is in apposition with the trachea H, and its external and

posterior sides correspond with the pleura. It is covered, anteriorly, immediately by the sterno-thyroid E, and sterno-hyoid F, a very loose cellular tissue only separating it from these muscles; this tissue is continuous inferiorly with that of the anterior mediastinum, and superiorly with the proper sheaths which the different cervical fasciæ furnish for the vessels of the anterior region of the neck; many sub-thyroid veins pass in this tissue, in order to open into the left subclavian vein. More superficially than those just named, are seen the sterno-cleido-mastoid D D, and lastly, the platysma-myoid muscle. The pneumo-gastric nerve 8, and the internal jugular vein 5, are situated much more outwardly; the left subclavian vein is situated very low, and in front of the origin of the arteria innominata, and however forcibly the neck be extended, it cannot be raised above the sternum. It results, then, that to arrive at the innominata trunk, the skin, platysma-myoid, sterno-mastoid, sterno-hyoid, and sterno-thyroid muscles must be divided, but in such direction as not to encounter any important nerve or vessel. But if, instead of carrying the examination directly from before backwards, and from above downwards, whilst following the middle of the space which separates the superior edge of the sternum A, and the extremity of the clavicle B, the dissection be carried in the direction outwards, we fall upon the pneumo-gastric and recurrent nerves, the internal jugular vein, and the principal branches given off from the subclavian artery.

When the operation of the ligature of the brachio-cephalic trunk is to be performed, the patient should be laid upon the back, the head forcibly carried backwards, in order that the neck may be extended, and the vessels proposed to be laid bare, be raised above the edge of the sternum: the face should also be slightly turned towards the left shoulder; the surgeon placed to the outside of the patient between the shoulder and and neck, must make an incision of at least three inches in length, commencing at the middle of the space which separates the two sterno-mastoid muscles, and prolonged towards the right shoulder. This incision must correspond about half an inch above the clavicle. Having made a section of the skin and the platysma-myoid, the mastoid muscles must then be divided in the same direction. But, in order to divide the sterno-hyoid and sterno-thyroid it is necessary to insinuate a director under these muscles so as to protect the origin of the primitive carotid 2, and innominata itself, from the action of the bistoury. The whole breadth of these muscles being divided, the operator must lay aside the bistoury, and only use blunt instruments for insulating the artery, such as the scalpel and dissecting forceps, and the grooved director. Though, if it be necessary to divide any of the sub-thyroid veins, the bistoury must be used for that purpose: or, if any of the small nervous filaments, arising from the junction of the hypoglossus and the first cervical pair, be found before the artery, he must also

use the bistoury in dividing them, taking the greatest care to insulate them so as to avoid the principal vessels. Great management is also necessary in insulating the artery at its external and posterior parts, that the lung be not torn. Lastly, when the artery is entirely insulated, the surgeon must glide his armed needle (in this case the handled hook is preferable to every other) on one side, between the artery, the pneumo-gastric nerve, and the lung, so that it may protrude on the other side, between the vessel and the trachea: this done, it only remains to tighten the ligature, by following the rules laid down when speaking of ligatures in general.

When the operation is over, the patient must be laid with his chest much elavated, and the head bent forwards and inclined rather towards the shoulder of the affected side, so that the lips of the wound may be easily approximated.

After the ligature of the brachio-cephalic trunk, the circulation is maintained in the right side of the head and neck, by the numerous anastomoses which the branches of the carotid and vertebral arteries of one side form with those of the opposite: and in the superior extremity, by the communications of the cervical arteries with those of the shoulder: the first aortic intercostals also communicate with the thoracic arteries.

II. THE SUBCLAVIAN ARTERY WITHIN THE SCALENI MUSCLES.

It has been proposed to tie the subclavian artery before its arrival between the scaleni muscles. The performance of this operation would be more difficult than the ligature of the innominata trunk, because its relations are more numerous than those of that vessel, both with the pneumo-gastric nerve 8, the internal jugular 5, and vertebral vein 6, the phrenic nerve 9, and the numerous branches which the artery itself furnishes before it arrives at the scalenus: in this subject the most part of these branches arise by a single trunk 4, which will render the operation much easier than when each branch has its separate origin from the subclavian. When this operation is performed, the patient must be placed in the same position as for the ligature of the innominata, and the incision must also have the same direction, and bear the same relations with regard to the clavicle, but it is not necessary to divide the sternal portion of the mastoid, and the incision must stop opposite the internal extremity of the clavicle. In placing the ligature, great care must be taken to insert it between the origins of the vertebral, internal mammary, inferior thyroid arteries, etc., and the origin of the subclavian. This necessity of passing the ligature within the branches which have just been named, renders the success of the operation much more uncertain when practised on the right than on the left side, because on this

side the subclavian arising immediately from the aorta, allows a much greater extent of space for the formation of the coagulum between the ligature and a large collateral branch, than on the right side. The performance of this operation is more difficult on the left than on the right side, the artery on the left being situated deeper: and independently of the numerous relations which have been pointed out on the right, the left has one in addition, formed by the presence of the thoracic duct, which opens into the subclavian vein in the vicinity of the artery. On the left side the nervus vagus passing before the aorta has no relation with the subclavian artery.

After the obliteration of the subclavian, before the origin of the thyroid, cervical, vertebral, scapular and internal mammary branches, the circulation is continued in the limb through the medium of the strong communications which these branches have with those of the opposite side.

A very distinguished English surgeon, Mr. *King*, formerly house-surgeon at the Hotel Dieu, has proposed a different mode of performing the ligatures which have been described: it consists in making an incision parallel to the most inferior portion of the internal edge of the mastoid, and following the cellular layer which separates this muscle from the sterno-hyoid and sterno-thyroid, in order to arrive on the right side, upon the trunk of the innominata and the origin of the subclavian: and on the left side upon the subclavian before its passage between the scaleni muscles.

In speaking of the ligature of the primitive carotid, a particular mode of operation, equally applicable to the ligature of the innominata, and subclavian arteries, in their intra-costal portion, shall be pointed out.

Plate IV.

Ligature of the Subclavian, and the Lingual Arteries.

I.

A—Central portion of the clavicle.
B. B—Sterno-cleido-mastoid muscle: its posterior edge divided.
C—Anterior scalenus muscle.
D—Omo-hyoid muscle.
E—Superior surface of the first rib.

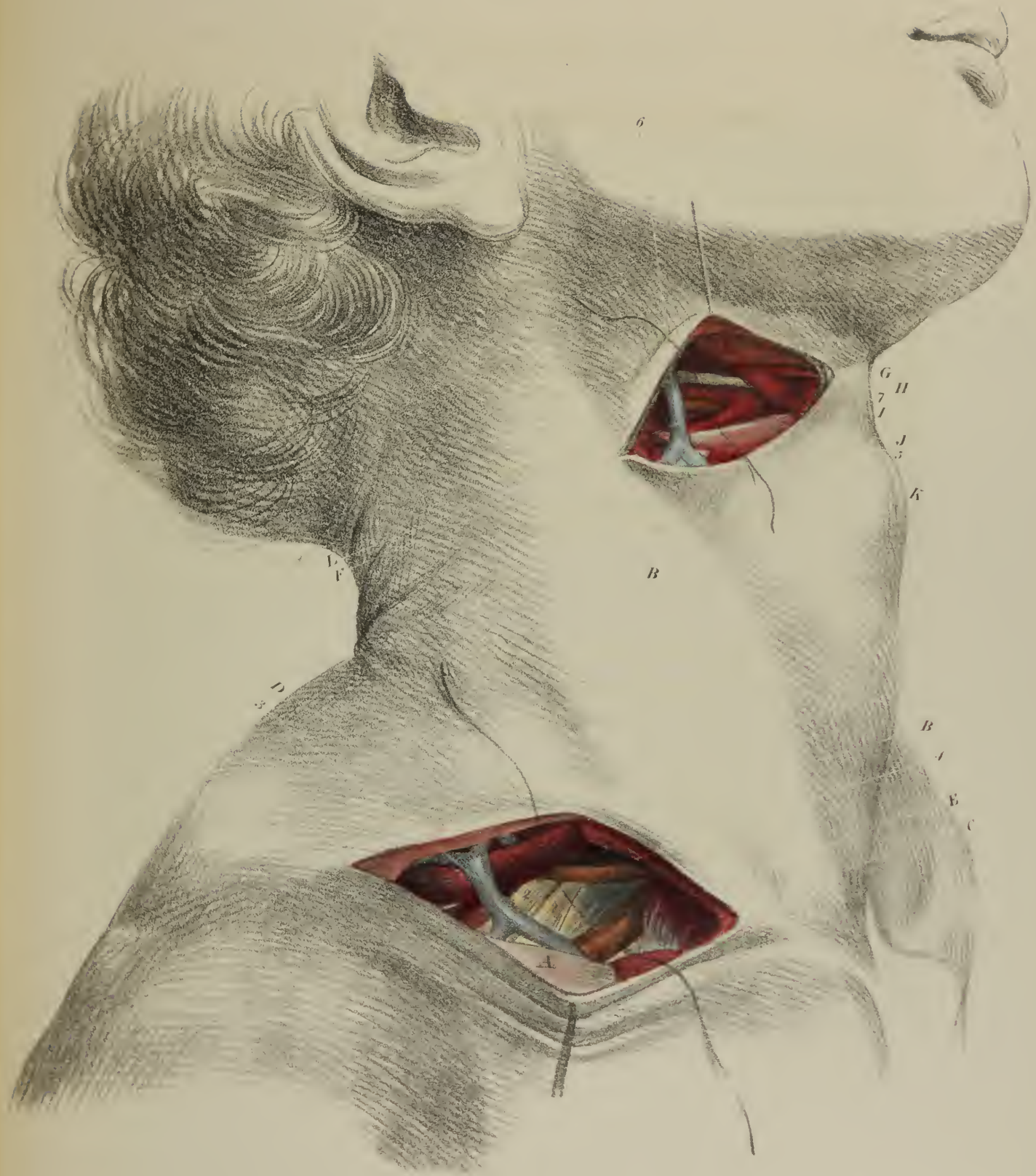
1—Subclavian artery.
2. 2—Nerves of the brachial plexus.
3—External jugular vein.
4—Transverse cervical artery.

II.

F—Great cornu of the os hyoides.
G—Sub-maxillary gland.
H—Tendon of the digastric.
I—Stylo-hyoid muscle.
J—Hyoglossus muscle divided.
K—Superior extremity of the thyro-hyoid muscle.
L—Middle constrictor muscle.

5—Lingual artery.
6—Facial vein.
7—Grand hypoglossus nerve.

PL. IV.



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I. THE SUBCLAVIAN ARTERY.

The works of Descriptive and Relative Anatomy do not indicate, in a precise manner, the point where the subclavian artery terminates and the axillary commences. In order to avoid, in the following description, any uncertainty in this respect, I have considered the external edge of the first rib, as its termination on both the right and left side. This observation will not, in the least, change the relations of these vessels, but is really intended to give precision to the phraseology.

It has already been said, that the two subclavian arteries, in one part of their course, differ from each other considerably: these differences are caused by the inequality of their length: the right being much shorter than the subclavian of the left side; and by the first arising from the innominata, and the second from the termination of the arch of the aorta: but when they arrive at the internal side of the scaleni muscles, they both present, nearly in every respect, the same relations, and preserve this similarity to their termination. Before they engage between the scaleni, the two subclavians give origin, in a very variable order, to the internal mammary, inferior thyroid, vertebral, superior scapular, and the different cervical arteries: and after furnishing the branches just named, these two vessels, on the right and left, gain the superior surface of the first rib and extend as far as its external edge. That of the left, in immediate contact with this bone, and that of the right, reposing only on its external part; from this latter arrangement, therefore, it is, that the left subclavian artery is situated deeper than the right. Both present the following relations: their inferior surface corresponds with the first rib E: their internal side with the anterior scalenus muscle C: and their external side is in contact with the nerves of the brachial plexus 2, 2, which separate the artery from the posterior scalenus muscle. It results, then, that the subclavian artery and the nerves of the brachial plexus are placed in the space between the two scaleni; the artery in contact with the anterior, and the nerves with the posterior. The subclavian vein has no connexion with the artery, these vessels being separated from each other by the whole breadth of the anterior scaleni: the vein to the interior and the artery to the exterior.

The relations which have just been pointed out are seldom altered. Though M. *Blandin* in his excellent work on Relative Anatomy, describes a case in which the subclavian vein passed behind the anterior scalenus muscle, and was, consequently, situated between that muscle and the artery. I once saw the subclavian artery passing before the anterior scalenus; it was placed between this muscle and the vein, which, on that account, was much nearer the sternal extremity of the clavicle than is

ordinary. In both these cases the contact of the vein with the artery would render the operation exceedingly difficult and much more dangerous.

In the plane which we have just described, a very loose cellular tissue, easily broken, and containing much fat, is found; the sub and supra clavicular nerves traverse this tissue from above downwards, and three or four lymphatic ganglia are also found embedded in it. Across these different parts two arteries ramify, which are very important to be known; one, the transverse cervical 4, generally very tortuous, is situated some lines above the subclavian, the other, the superior scapular, which is not seen in the plate, runs along the posterior edge of the clavicle. From this disposition the parts, it results that in order to arrive at the subclavian artery, we must pass of between these two arteries.

More superficially than the plane just described the omo-hyoid muscle D is found, and from its inferior edge a fibro-cellular expansion proceeds, and is continuous, below, as far as the inferior surface of the clavicle, and, within, with the deep layer of the fasciæ of the neck. Upon the omo-hyoid muscle and the layer just mentioned, the external jugular vein 3 is found, which, passing below the clavicle, opens into the termination of the subclavian, or the commencement of the axillary vein. At other times, the jugular vein divides into two or three branches, separated more or less from each other, and opening separately either into the trunks just mentioned, or into those of smaller size, as the superior scapular or transverse cervical veins. Upon the same plane with the external jugular vein, and rather more internally, the sterno-mastoid muscle B is found: the posterior edge of which will always correspond either with the internal, or middle, or external side of the trunk of the subclavian; lastly, still more superficially, the platysma-myoid muscle and the skin are met with.

In order to tie the extremity of the subclavian artery, the patient must be laid or seated on a chair, the shoulder and clavicle being depressed as much as possible; unfortunately this is almost always impossible from the nature of the disease itself which renders the operation necessary. In fact, an aneurismal tumour of the axillary artery will forcibly raise the shoulder, and cause the subclavian artery to be very deeply situated; hence, all practitioners advise the ligature of the artery to be performed before the tumour has acquired a large size. The shoulder being depressed, the head and neck must be slightly inclined towards the shoulder of the healthy side: and the surgeon having ascertained precisely the situation of the external jugular vein, in order to avoid that vessel, in making his section of the skin and platysma-myoid muscle, then searches for the posterior edge of the sterno-cleido-mastoid muscle, which, as before stated, corresponds with the situation of the subclavian artery. Having taken

these precautions, he makes an incision with a convex-edged bistoury, eight or ten lines above the clavicle and parallel to the posterior edge of that bone; the anterior extremity commencing upon the posterior part of the sterno-cleido-mastoid, and its posterior prolonged more or less behind, towards the trapezius. In general three inches will be sufficient in length; though if the soft parts are very thick, a greater length will be necessary; should this be the case, it must be done by extending it behind, for if the incision, on the contrary, should be extended internally, we fall upon the subclavian and the inferior part of the internal jugular vein, a thing always to be avoided. When the operation is well performed, these veins are not to be seen. In our plate, the great extent of the division of the sterno-cleido-mastoid, is for the purpose of more clearly exposing the scalenus muscle. In general it is sufficient to divide about four or five lines only.

The skin and the platysma-myoid divided, the position of the internal jugular vein is exposed; and, by means of a blunt hook, an assistant must draw it towards either angle of the wound accordingly as it was originally situated. This done, a portion of the sterno-cleido-mastoid, and the sub and supra clavicular nerves, which have not been divided along with the platysma, must be cut across. After this, the operator will only use a cutting instrument to divide the more resisting tissues; and, in this case, he will always take care to insert the grooved director under the parts. It is seldom necessary to use the bistoury to cut the deep layer of the cervical fascia. Immediately after the division of the parts just mentioned, the indicator finger of the left hand, if operating with the right, and the right, if operating with the left, must be placed in the anterior angle of the wound, in order to find the prominence of the anterior scalenus, and passing the finger over the inferior and posterior part of that muscle upon the first rib, he ascertains the artery to be situated immediately behind the osseous tubercle upon which the last named muscle is inserted. Professor *Lisfranc* insists, with much reason, upon the facility by which the subclavian artery can be found, by taking this osseous tubercle as a guide. This point once known, the surgeon need not to extend his examination, for he will soon perceive the situation of the artery by its pulsations. If, on the contrary, he continues his examination from one part of the wound to another, the operation will be tedious and painful, and, consequently, the probabilities of success, as stated in the General Principles, very greatly diminished.

The artery insulated, it must then be surrounded with the ligature by means of the handled needle, or a flexible probe needle, or, if the wound be very deep, *Desault's* spring needle may be advantageously used. The artery tied, the patient must be placed in bed, and the neck flexed towards the affected shoulder, so that the lips of the wound may be approximated.

The performance of this operation has been frequently unsuccessful, though sometimes the contrary, especially by M. M. *Dupuytren*,* *Past*, and *Ramsden*.

After this operation, the circulation is by degrees re-established in the limb by means of the large anastomoses which the transverse cervical, deep cervical, and superior scapular, possess with the other arteries of the shoulder.

II. THE LINGUAL ARTERY.

The lingual artery has never, to my knowledge, been tied upon the living subject: but, for some years past, many surgeons have advised this operation to be performed, and for eight years that I have taught Operative Medicine, my pupils have always practised it.

Beclard has also proposed this operation, in the cases where a deep extirpation of the posterior part of the tongue would be necessary. In fact, it is to be feared, in these cases, that hæmorrhage cannot be arrested by the eschar from the actual cautery, (the only available means to suppress these hæmorrhages,) the artery of this region possessing a sufficient force to cause that accident. It would not be necessary to tie both the lingual arteries; a slight cauterization being sufficient to arrest the flow of blood on that side where the artery has been divided near the apex of that organ. The double ligature would only be required, when the whole of the tongue has been amputated at its base. The ligature of the lingual artery may also be a valuable remedy in certain organic diseases of the tongue instead of its extirpation.

The lingual artery 5 arises from the anterior part of the external carotid, generally by a single trunk, at other times by a trunk common to it and the superior thyroid, or the facial, and sometimes to both these vessels. Whatever be its mode of origin, the artery afterwards directs itself towards the superior part of the great *cornu* of the os hyoides F; arrived at that point, it enters between the middle constrictor muscle of the pharynx L, and the hyoglossus muscle J, it then proceeds forward and upward towards the base of the tongue; so that the nearer it approaches the median line, the further it removes from the os hyoides. It is situated behind, about one line from the great *cornu*, and in front, it becomes separated eight or ten lines from the body of the bone. The vein which accompanies this artery is so small, as not to require to be taken into consideration. The great hypoglossus nerve 7 is much further from the

* In the case operated upon by M. Dupuytren, the ordinary mode of proceeding was impossible, on account of the great elevation of the clavicle; this celebrated surgeon found means to obviate this difficulty, by dividing the anterior scalenus muscle.

os hyoides than the artery, and is separated from the latter by the breadth of the hyoglossus muscle J. Towards the posterior extremity of the great cornu, but more superficial than the parts just named, the facial vein 6 is seen descending into the jugular. More internally and upon the same plane, the inferior extremity of the stylohyoid muscle I, the tendon of the digastric H, and the inferior edge of the sub-maxillary gland G, are perceived.

In practising the ligature of the lingual artery, I have constantly employed the following method; which appears to me preferable to those hitherto proposed. The subject being laid upon the back, the head inclined backward and the face turned towards the healthy side; the surgeon must carefully ascertain the situation of the os hyoides, which will serve as a guide during the whole progress of the operation, an incision must then be made from an inch to fifteen lines long, commencing a little behind the *cornu* of the os hyoides and prolonged upward and forward about half an inch above the body of that bone. The skin and the platysma-myoid muscle being divided, the facial vein must be avoided, and carried backward: this precaution is often unnecessary, from that vessel being situated very backward. The cellular sheath of the sub-maxillary gland must then be opened, and that body elevated, without wounding its tissue. This done, the digastric H, and stylo-hyoid I, as well as the hypoglossus nerve 7, will immediately be seen. If these different organs are too near the os hyoides, as may be the case in very short-necked subjects, they must be slightly raised so as to admit of the external surface of the hyoglossus muscle J being more easily exposed. When this muscle is exposed, it must be raised, by means of the dissecting forceps having hold of a few of its fibres, and a grooved director passed beneath, so that its section may be made with the bistoury. This section made, the artery is uncovered, and can easily be insulated, on account of its great mobility, between the middle constrictor and the hyoglossus.

Plate V.

Ligature of the Primitive Carotid, the Facial, and the Temporal Artery.

I.

A—Sternal extremity of the clavicle.
B. B—Sterno-cleido-mastoid muscle.
C—Sterno-hyoid muscle.
D—Sterno-thyroid muscle.
E—Omo-palato-hyoid muscle.
F—Edge of the thyroid gland.
G—Platysma-myoid muscle cut.

1—Primitive carotid artery. 2—Internal jugular vein. 3—Pneumo-gastric nerve. 4—Plexus of the descendens noni and first cervical nerve, and the filaments which it furnishes.

II.

H—Masseter muscle.
I—Platysma-myoid muscle.
J—Inferior maxillary bone.

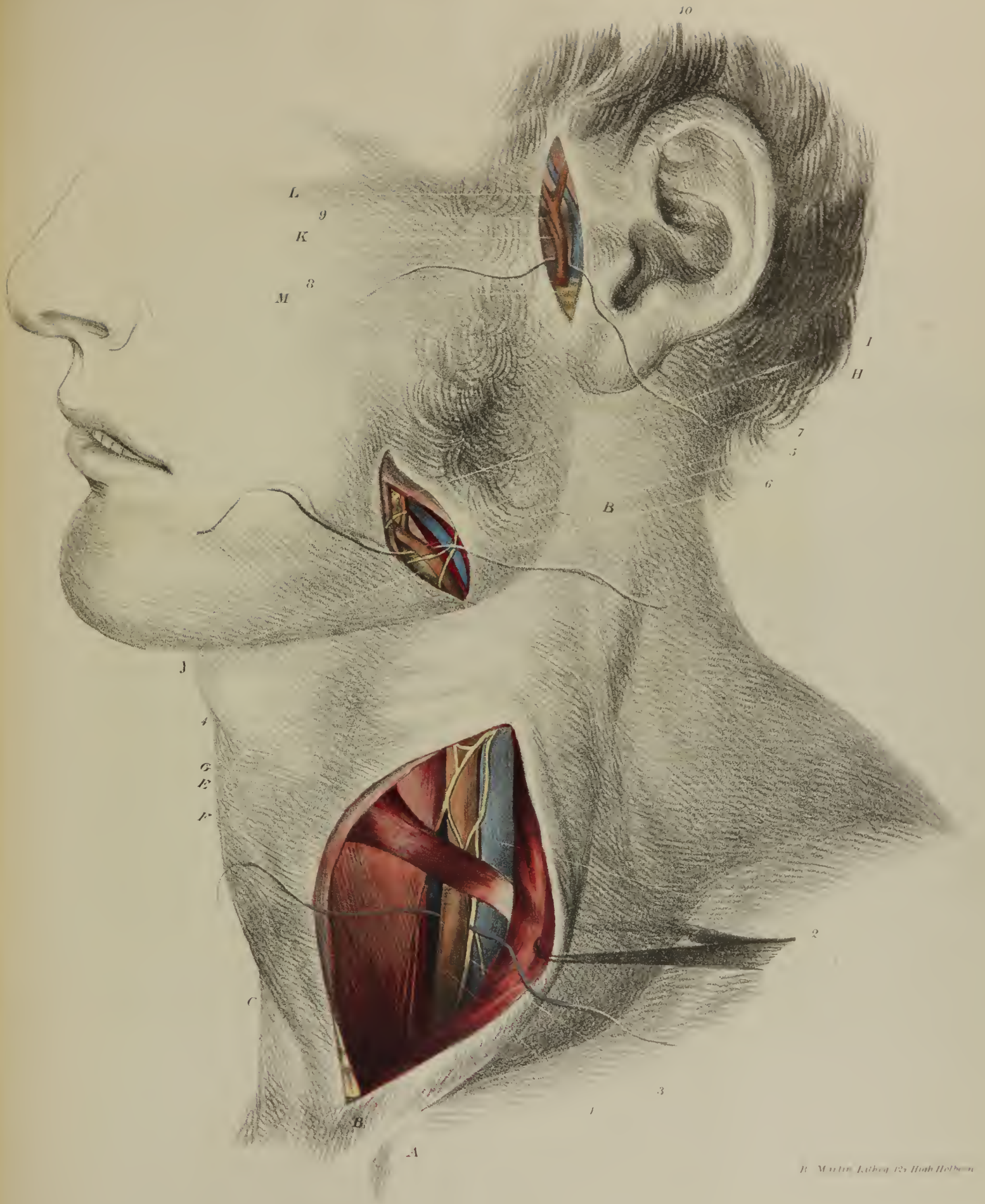
5—Facial artery. 6—Facial vein. 7—Some filaments of the facial nerves.

III.

K—Zygomatic arch.
L—External aponeurosis of the temporal muscle.
M—Superior extremity of the parotid gland.

8—Temporal artery. 9—Middle temporal artery. 10—Temporal vein.

PL. V.



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I. THE PRIMITIVE CAROTID ARTERY.

The primitive carotid artery has frequently been tied during the last twenty-five years: and without immediately inducing the least disturbance either in the functions of the brain, or in the vitality of the other parts of the head: it will therefore be unnecessary to demonstrate its perfect safety. It is further thought that both primitive carotid arteries may be tied at the same time, in the same individual, without being followed by any particular or durable derangement of the functions of the different parts of the head: the numerous anastomoses which exist in the interior of the skull, between the terminating branches of the vertebral arteries and those of the internal carotids, are more than sufficient to carry the blood easily from one to the other; so as not sensibly to affect the brain by the obliteration of the two carotids. The frequent communications also which exist, externally, between the branches of the external carotids and those of the two subclavians, especially the large anastomoses of the inferior with the superior thyroid, and of the ascending cervical with the occipital arteries, etc.; leave not a doubt of the possibility of the continuation of the vitality of the neck and the remainder of the head.

Relying upon the deductions obtained from the consideration of the distribution of the arterial system, I can also give the results which I have obtained from the frequent practice of the ligature of the two primitive carotids upon living animals; having never remarked the slightest alteration either in their intelligence, or their general health. A very large dog is still alive at the Theatre of the Hospital, upon which I performed this double operation, four years ago, and yet the animal has not the less attained a remarkable growth, nor does its intelligence appear to be less than if it had not undergone this operation.

I am so convinced of the little danger, that can follow the ligature of the two carotids, allowing for the general inconvenience attending the ligature of a large trunk, that some years ago, I proposed this operation in a young man who was under M. *Serres*, in the Hopital de la Pitie. He entered the hospital for an intestinal complaint, but also presented an affection of the capillary vessels of the face, which had transformed the whole of the right cheek, both lips, and the internal part of the left cheek, into erectile tissue, appearing to M. *Serres* and myself, to be in its first degree of developement. This disease not occasioning any immediate inconvenience, the patient would not believe that it might prove dangerous: he therefore refused to undergo the operation.*

* It is hardly necessary to state that this serious operation was not determined upon until all other means had been found insufficient: but the patient refused all treatment, and when cured of the abdominal affection, left the hospital.

The two primitive carotid arteries, like the subclavians, exhibit a remarkable difference, the one from the other; the right being much shorter than the left; the first arising from the innominata trunk, and the second from the arch of the aorta. Excepting this inequality of length, and the consequent differences in their relations, the carotids on both sides present precisely the same connexions. Both terminate opposite the superior edge of the larynx; their posterior part resting upon the long muscles of the neck and the cervical vertebræ, their internal side, inferiorly, touching the trachea, their external side, superiorly, the thyroid body F, the larynx and pharynx: they are in contact with the internal jugular vein 2, and the pneumo-gastric nerve 3, which occupies the posterior part of the cellular layer separating these two vessels.* Lastly, upon the anterior side of both carotid arteries and jugular veins, superiorly, the plexus of nerves 4, formed by the union of the two descending branches, furnished by the great hypoglossus and the cervical pair, and inferiorly, the nervous filaments given off from that plexus, are found immediately applied upon these vessels. In a more superficial plane, the omo-hyoid muscle E, passes obliquely from below, upward, and from without, inward, across the direction of these vessels: from both edges of this muscle a fibro-cellular expansion is given off, extending above and below upon the vessels and nerves just mentioned. Still more superficially, the sterno-mastoid muscle B, B, is found, by its internal surface in contact with the primitive carotid and the internal jugular vein. Below, near their origin the two carotids are separated from the sterno-cleido-mastoid by the sterno-hyoid C, and sterno-thyroid D: the platysma-myoid G, and the skin cover the sterno-mastoid.

Every surgeon who has performed the ligature of the primitive carotid, has followed the same proceeding, each having taken the internal edge of the sterno-cleido-mastoid, as a guide to the artery. In performing this operation, the patient must be laid in the recumbent position, the head slightly extended and held by assistants: the operator placed on the affected side, makes an incision along the internal edge of the sterno-cleido-mastoid at least three inches long, by which he divides the skin and platysma-myoid muscle: he then divides the layer of cellular tissue uniting the mastoid with the sterno-hyoid and sterno-thyroid muscle. Having done this he separates these muscles from each other with the fingers, and with a blunt hook draws the sterno-mastoid outwards, at the same time, ordering the patient's head to be slightly flexed, that the edges of the wound may be more easily separated. This being done, the jugular vein is seen, which, on account of its great dilatation, fills the bottom of the wound, and hides the carotid artery and pneumo-gastric nerve.

* In the plate, this nerve has been raised in the inferior two thirds of the wound, in order to render it apparent, otherwise it would have been hid behind the vessel.

Before any attempt is made to insulate the artery from the vein, the fascia arising from the edges of the omo-hyoid muscle, and the muscle itself, if it occupy the middle of the wound, must be divided upon the grooved director. The same must be done with the nervous filaments which pass from one vessel to the other. Having completed these sections, the surgeon again lays aside the bistoury and gently separating the vein from the artery, glides the ligature needle between these two vessels, taking great care to leave the nervus vagus adherent to the vein.

The ligature accomplished, the patient must be laid with the head slightly flexed upon the chest, so that the artery may not be extended.

A very distinguished military surgeon, M. *Sedillot*, has proposed a different mode of tying the primitive carotid, than the one just described; this method is equally applicable to the ligature of the innominata trunk, and the two subclavian arteries within the scaleni muscles. It is as follows: the patient being laid, the neck extended, and the head inclined towards the healthy side, so that the sterno-cleido-mastoid muscle may be well stretched, the surgeon makes an incision from two to three inches, proceeding from the internal extremity of the clavicle, and prolonged upward and outward, in the direction of the layer of cellular tissue, separating the clavicular from the sternal portion of the mastoid muscle. The different layers of condensed cellular tissue, covering the internal jugular vein, must be then successively divided, observing the necessary precautions, the artery is thus arrived at, by passing before the anterior scalenus muscle, and the diaphragmatic nerve. On the right side, following this method, it is very easy to expose the innominata trunk.

The same method leads to the carotid artery by a still shorter way: the wound is also less oblique: I think, however, that it would only be applicable to the left carotid; on the right, the vessel being much shorter, the ligature would approach too near its origin.

The External and Internal Carotid Arteries.

The external and internal carotid arteries should never be attempted to be tied except when consequent upon a large wound the open ends of the vessel can be seen, or when during the performance of an operation these arteries are met with. At their origin, however, these vessels are sufficiently superficial so as to allow of being easily reached: but the ligature would be so near a collateral branch, that except both arteries were tied at the same time, hæmorrhage would certainly follow at the decidence of the ligature. I think also, that consequent upon a wound of the superior and lateral part of the neck followed by hæmorrhage, it would be impossible for the practitioner

to ascertain whether the blood was furnished by the extremity of the primitive carotid, the commencement of the internal and external carotids, or by one of the principal branches of the latter. In these uncertain cases, he should not hesitate to tie the primitive carotid. If, on the contrary, the wound be so situated, that it may be possible to decide from what artery the blood proceeds, he must then only tie the wounded artery.

II. THE FACIAL, OR EXTERNAL MAXILLARY ARTERY.

The ligature of the lingual artery having already been spoken of; that of the facial and temporal shall now be described, and, under the following plate, that of the occipital.

The external maxillary or facial artery should never be tied in its sub-maxillary portion, being situated too deep, and surrounded by such numerous soft parts, that its insulation would be difficult: but having once arrived at the external surface of the inferior maxillary bone this operation is very easy. This artery 5 rests immediately upon the maxillary bone J, in contact with the anterior part of the masseter muscle H, and accompanied by a single vein 6, which is always found at its posterior side, though sometimes it is placed two or three lines behind the artery. Some branches of the facial nerve 7 pass transversely across the maxillary artery and vein: lastly, the platysma-myoid muscle and the skin cover all these parts. The solid plane upon which this artery rests, and the thinness of the soft parts which cover it, facilitating its compression, ought to render the necessity of its ligature very rare. This operation, however, has been very frequently performed.

The patient being laid, the head inclined towards the opposite side to that upon which the operation is to be performed; the surgeon makes an incision, along the anterior edge of the masseter, about an inch long, taking care to give it an oblique direction from below upward, and from behind forward, according to the course of the artery, and of the fibres of the platysma-myoid. The skin and the platysma-myoid divided, the cellular tissue and the filaments of the facial nerve 7 must be cut in the same direction, until the inferior part of the masseter muscle H is exposed. The facial vein 5 rests upon this muscle: and the artery is always before it: once exposed, the artery is easily insulated, and its ligature effected.

III. THE TEMPORAL ARTERY.

Of the two branches which arise from the termination of the external carotid, the internal maxillary is situated too deep to allow of its ligature: this is not the case with the other branch, known under the name of the temporal artery 8; it may be very easily tied in its passage over the zygomatic arch K; lower down it is covered by the summit of the parotid gland M, so that it cannot be tied there without difficulty. The temporal vein 10 is situated between the artery and the auditory canal. The cellular tissue which unites these vessels, between them and the skin, is dense, compact, and does not contain much fat; so that it is always very difficult to detach and insulate the artery.

The cases in which the ligature of the temporal artery is necessary are very rare; compression being generally sufficient to arrest the hæmorrhage, either from a wound of a branch or the trunk of this artery. Under some circumstances, the ligature of one branch may be sufficient, but in others, that of the trunk may alone prove effectual. This is the case when a wound divides the temporal muscle as well as the skin; that is, when the superficial and middle temporal branches 9 may have been cut. In this case, it is indispensable to secure the artery below the zygomatic arch; because, without this precaution, the superficial branch only will be tied.

Before performing this operation, the surgeon must ascertain, by the touch, the position of the artery: the patient being laid upon the side, an incision must then be made about an inch long, corresponding with the middle of the space which separates the temporo-maxillary articulation from the auditory canal; the skin having been divided, a grooved director must be inserted under the layers of cellular tissue which cover the artery and vein, as it will be impossible to break this tissue with any blunt instruments.

Plate VI.

Ligature of the Axillary below the Clavicle, and the Occipital Artery.

I.

A—Great pectoral muscle, cut.
B—Internal edge of the deltoid muscle.
C—Superior edge of the little pectoral muscle.
D—First external intercostal muscle.

1—Axillary artery. 2—Axillary vein. 3—Nerve of the brachial plexus. 4—Superior extremity of the cephalic vein: before opening into the axillary vein it receives many branches, as the thoracics and acromial. 5—Trunk common to the thoracics and acromial arteries.

II.

A—Mastoid process of the temporal bone.
B—Aponeurosis of the sterno-cleido-mastoid muscle, cut.
C—Cephalic portion of the spenius muscle, divided.
D—Posterior edge of the complexus muscle.
E—Superior oblique muscle.

6—Occipital artery. 7. 7—The two accompanying veins, anastomosing with each other over the artery.

PL. VI.

I. THE AXILLARY ARTERY.

The ligature of the axillary artery below the clavicle is, perhaps, the most difficult of those which have been performed. The difficulty arises from the depth of its situation, and its intimate relations with the axillary vein and the nerves of the brachial plexus. This operation, however, has been performed a great number of times, and often successfully, especially by M. M. *Maunoir*, *Keate*, and *Chamberlain*; though it must also be stated that other practitioners of great merit, under other circumstances, have not been so successful; as in the cases of *Desault*, *Pelletan*, and *White*. The name alone of these surgeons is sufficient to prove, how great the difficulties must have been, since they could not be entirely surmounted. In these cases many nerves of the brachial plexus had been included within the ligature.

The cases in which the ligature of the axillary is necessary, are, aneurisms of the inferior or superior part of the brachial artery, and wounds of the axillary in its passage through the axilla. M. *Dupuytren* once performed it for an aneurism of the subclavian and of the innominata trunk. The patient sunk some days after the operation.

In speaking of the ligature of the subclavian we have considered that artery as terminating below the first rib; so that following that rule, the axillary artery will be slightly shortened. That artery 1 having arrived below the first rib, descends upon the lateral and superior part of the thorax: it rests upon the first external intercostal muscle, the second rib, the superior digitations of the serratus magnus, and gains the internal side of the head of the humerus: it is in relation with the vein of the same name, and the nerves of the brachial plexus. Above the clavicle, we have shewn that the subclavian artery is separated from the vein by the breadth of the anterior scalenus muscle; but, as this muscle terminates on the first rib, it follows that beyond that bone, the vein 2 approaches very near the artery, and ends by covering its internal and anterior part: the brachial nerves 3 always keep the external side of the artery until their arrival at the small pectoral muscle C: but at the superior edge of that muscle, or rather its posterior part, these nerves give off the thoracic nerves, which, from their origin, pass before the artery, and rather lower this vessel is found still surrounded by numerous and much larger fasciculi; so that its insulation, in this part of its course, would be very difficult; and if it be considered that, in the same part, the axillary vein receives the acromial, thoracics, and many scapular veins, which pass before and behind the artery, it will be allowed that the ligature of that part

of the axillary artery should not be attempted. Below the small pectoral muscle, upon the plane occupied by the vessels and nerves, a loose, fragile, cellular tissue is found, containing many small venous and arterial vessels, and some nervous filaments, which may be divided with the bistoury : it is seldom that any lymphatic ganglia are found in this tissue. The axillary vessels, superiorly, are covered by the subclavian muscle and the clavicle; inferiorly, by the great and small pectoral muscles, and lastly, by the platysmo-myoid and the skin. Between the posterior surface of the great pectoral muscle and the axillary vessels, a fibro-cellular layer is found, sometimes resembling a thin aponeurosis : this fascia arises from the inferior edge of the subclavian muscle, and from the costo-clavicular ligament, and is lost in the axillary cavity by dividing into two layers, one passing before and the other behind the small pectoral muscle.

From what has preceded, it will be seen that to arrive upon the axillary artery, after having divided the skin and platysma-myoid, a portion of the great pectoral must also be divided its whole thickness. In order to perform this operation, the patient must lay with the shoulder rather elevated, so that the artery may be a little separated from the vein ; to attain this end, the elbow must be apart four or five inches from the body: the surgeon then makes an incision two or three inches long, according to the thickness of the soft parts; its external extremity commencing upon the internal part of the deltoid muscle B, and prolonged more or less towards the internal extremity of the clavicle, it should be parallel with the anterior edge of that bone and about eight or ten lines above. In giving this direction to the incision an advantage arises in being able to arrive directly upon the vessels and nerves from before, backward, so that the artery can be more easily insulated : on the contrary, when the incision is parallel to the layer of cellular tissue separating the clavicular from the sternal portion of the great pectoral; it is true its fibres are not divided, but the wound does not correspond with the direction of the artery ; at the same time, it is situated internally with respect to the vein, so that to arrive at the artery to be tied, the attention must be directed, below and within, to pass over the vein, which, from its great size, renders the operation very difficult. To avoid these difficulties, it is better to divide the great pectoral for an inch or two, the section of so small a portion of this muscle not being likely to diminish in a perceptible degree the strength of the arm.

The skin and the great pectoral muscle having been divided, all the vessels so large as to furnish a jet of blood must be secured ; and I may mention, that in the operation, it is sometimes necessary to apply a great many of these ligatures. M. *Dupuytren* has applied as many as twelve or thirteen before arriving at the axillary artery; in this situation there certainly are not twelve, perhaps not more than three or four branches

requiring a ligature after their section : but as these arteries proceed from the deep to the superficial parts, it follows that, in advancing from the skin towards the deep parts, the same vessel must be divided many times over.

In making this incision, care must be taken to avoid the cephalic vein 4, as it ascends in the space between the deltoid and the pectoral muscle. In most cases, this vein penetrates from before, backward, towards the axillary, an inch or fifteen lines from the clavicle ; so that there would be no danger of wounding it, by an incision made above that ; but if, as I have frequently seen, this vein ascends within a few lines of the clavicle, it would be in danger of being opened by the first process of the operation. If this accident should ever happen, the vein must be included in a ligature. Having arrived at the posterior surface of the great pectoral, the superior edge of the small pectoral must be examined, and the aponeurotic layer which covers the vessels be divided above this point, upon a grooved director inserted beneath ; the cellular tissue immediately surrounding the artery must then be divided either with the forceps, director, or the handle of the scalpel ; and this being done, the vein is then brought into view, which, from its size, covers the internal side of the artery.* The surgeon will then carry this vein to the inside, and gliding the ligature needle between it and the artery, will bring it out at the opposite side between the first fasciculus of the brachial plexus and the artery ; and having surrounded it, he will, before making the knot, assure himself of the position of the thread relatively with the origin of the acromial and thoracic arteries : it is of the utmost importance that the ligature should be placed above the origin of these arteries, for without that, they would prevent the formation of the coagulum. The artery tied and the dressings completed, the arm must approach the body, so that the parts which compose the axilla may be placed in approximation.

After this operation, the blood is carried to the shoulder and arm by the same branches, as after the ligature of the subclavian upon the first rib, unless the obliteration has been made below the acromial and thoracic arteries : this must always be avoided.

* This vein, like all others near the right cavities of the heart, is found considerably enlarged, from the constant state of spasmodic action, which exists during the operation, rendering the respiration short and difficult ; the blood not finding a free circulation through the lungs, stagnates in the right cavities of the heart and extends its influence into the large venous trunks.

II. THE OCCIPITAL ARTERY.

The occipital, like the temporal, and in general like all the arteries which rest upon a solid plane, and are not covered by thick soft parts, ought only to be rarely tied: compression, if properly applied, being sufficient to arrest the hæmorrhage from this vessel. It is only under particular circumstances, where it is necessary for the compression to be continued for many days, that the ligature need be applied. Sometimes, however, in wounds of the hairy scalp with lesion of the branches of the temporal or occipital artery, where the slightest pressure upon the lips of the wound or other parts of the head is sufficient to cause an erysipelatous inflammation of the cranial integument. A prudent surgeon perceiving the slightest tendency to this accident, will abstain from every kind of pressure from the head, and if the hæmorrhage require, perform the ligature of the wounded artery, either within the same wound if recent, or, if not, upon another point of its course.

The occipital artery 6, can only be tied in its cranial portion, from the point where it escapes from under the complexus muscle. At its origin from the posterior part of the external carotid, and during its course before the transverse processes of the first three or four cervical vertebræ, it is placed too deep for its ligature to be attempted. It would, moreover, be impossible in a case of hæmorrhage from a wound of the lateral and superior part of the neck, to discover whether the blood proceeded from the occipital, the internal or external carotid artery, etc.; this uncertainty would compel the surgeon to have recourse to the ligature of the primitive carotid, rather than attempt to search for the trunk or perhaps trunks which supply the hæmorrhage. When it is necessary, therefore, to tie the occipital artery, it must always be done beyond the mastoid process and the small complexus muscle.

After its arrival above the atlas, the occipital artery 6, bends from before, backward. Situated between that vertebræ and the mastoid process A, consequently covered by all the muscles which are inserted into that prominence; and having arrived beyond the small complexus, it is found above the superior oblique muscle E, resting immediately upon the mastoid portion of the temporal bone, and running in a direction upward and backward, accompanied by its two veins 7: these veins are very large compared with the artery, and frequently anastomose with each other across the artery, so as to render its insulation very difficult. This difficulty, however, is still more increased by the solidity and tension of the cellular tissue, which unites these vessels: the splenius muscle and the aponeurosis of the sterno-mastoid going to attach themselves to the superior occipital ridge, alone cover this artery; therefore, to perform

its ligature, it is only necessary to make an incision through the skin and muscles just named. This incision must commence six lines behind and a little below the summit of the mastoid process, and extend obliquely upward and backward for an inch or fifteen lines: the skin and the sterno-mastoid aponeurosis being cut, the finger must be inserted under the superior lip of the wound to examine for the base of the mastoid process; the artery being placed two lines below, in the posterior part of the digastric furrow. These parts being recognised, and the whole thickness of the splenius divided in the direction of the first incision, the finger may then be used to find the pulsations of the artery. Its insulation must be made with great caution, that the accompanying veins be not torn. These veins furnish much blood, from their communication with the lateral sinus by the mastoid foramen.

I have often seen the occipital artery passing before the small complexus; in this case, it is almost always lower than ordinary.

Plate VII.

Ligature of the Termination of the Axillary, and the Brachial Artery.

Figure First.

I.

A—Inferior edge of the great pectoral muscle.
B—Coraco-brachial muscle.
C—Tendon of the teres major muscle.

1—Axillary artery. 2—Axillary vein. 3—Median nerve; its two roots very distinct. 4—Internal cutaneous nerve. 5—Ulnar nerve. 6—Radial nerve and some filaments of the thoracic and scapular nerves.

II.

D—Biceps muscle.
E—Inferior extremity of the coraco-brachial muscle.
F—Internal part of the triceps brachial muscle.

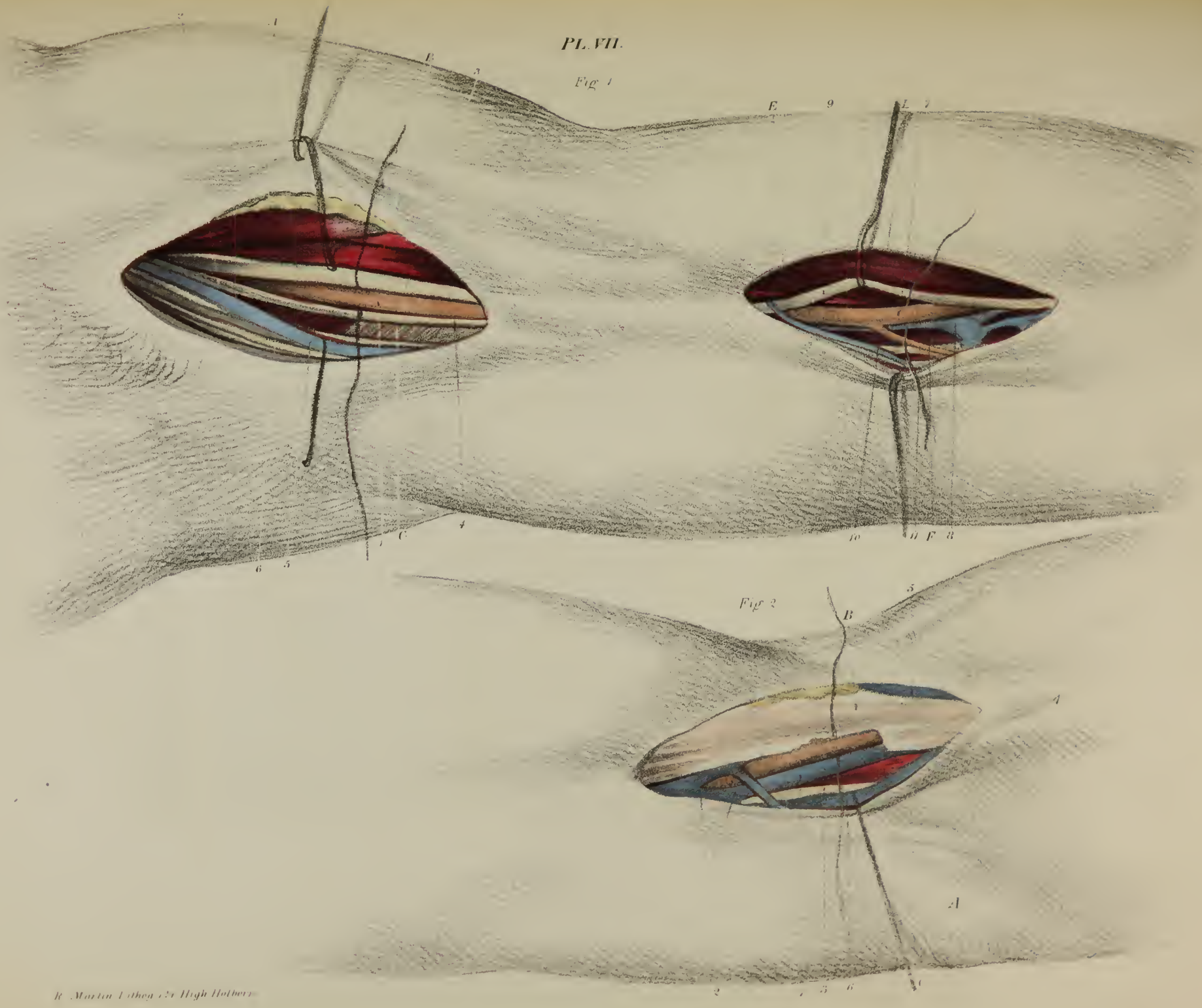
7—Brachial artery. 8—Brachial veins. 9—Median nerve. 10—Internal cutaneous nerve. 11—Ulnar nerve.

Figure Second.

III.

A—Internal condyle of the humerus.
B—Tendon of the biceps; its aponeurosis divided in order to show the brachial vessels.
C—Anterior brachial muscle.

1—Brachial artery. 2—Its accompanying veins. 3—Median nerve. 4—Median vein. 5—Median cephalic vein. 6—Median basilic vein.


PL. VII.
Fig 1
Fig 2

I. THE AXILLARY ARTERY.

In speaking of the relations of the axillary artery below the clavicle, it was seen, that in one part, in proportion as the vessel descends in the axillary space, it becomes much nearer the vein: and that in another, it is surrounded by the communicating fasciculi of the brachial plexus of nerves, so as to render the insulation of the artery very difficult. When it is considered how much this difficulty is yet increased by the thickness of the soft parts through which the operation must be performed, I think it will be admitted as being very imprudent in a surgeon attempting the ligature of the axillary artery between the small pectoral muscle and the inferior part of the sub-scapular. Independently of the great difficulty in the performance, this portion of the artery is not the most favourable for the success of the operation, on account of the numerous branches which it gives off within that space; so that the ligature would be endangered by being placed immediately below any of these branches. From these considerations, it will be thought better to tie the axillary artery at its superior rather than its middle portion, in the case of a wound or aneurism occupying the inferior part.

If it be extremely difficult to expose the axillary artery in its passage behind the pectoral muscles, where it is surrounded by the brachial plexus of nerves, and the numerous venous branches which open into the axillary vein: this is not the case after its arrival opposite the inferior edge of the great pectoral muscle. Thus, the brachial plexus no longer exists, the different nerves proceeding from it have all taken their route towards their respective destinations, and the artery itself is only covered by the skin, and the aponeurosis of the arm, in such manner that its exposure and insulation, in this region, becomes very easy. These are its relations, when the arm is at a right angle with the trunk; posteriorly, it rests upon the tendons of the teres major, and latissimus dorsi C: anteriorly, it corresponds with the coraco-brachial B, from which it is separated by the median nerve 3; internally, it is accompanied by the internal cutaneous nerve 4, and the axillary vein 2: this vein presents many varieties; it is often found in two or three branches, which render the relations of the artery more complicated, and, consequently, its insulation more tedious and difficult, than when the vein is single, as in the subject from which the plate was drawn. More posteriorly than the axillary vein the ulnar 5 and radial 6 nerves are seen. It is very important perfectly to know the position and relations of these nerves, that they may not be confounded with the median.

To perform the ligature of the termination of the axillary artery, the patient must be laid upon the back, the arm separated from the body: the surgeon placed before or

behind the patient, makes an incision from one to two inches long, according to the stoutness of the individual, commencing six or eight lines within the anterior edge of the axilla A. By the first incision, the skin and sub-cutaneous cellular tissue only are cut. Having made this incision, the aponeurosis of the arm must be taken hold of by the dissecting forceps, and an opening made with the bistoury in the horizontal position : through this opening the grooved director must be inserted, and the aponeurosis divided to the same extent as the external incision. If the aponeurosis be weak, this opening will be sufficient ; but if the contrary, it will be advisable to make a crucial incision, by dividing each edge of the primary incision : this precaution renders the remaining part of the operation much easier. Having divided the skin and the aponeurosis, it is not further necessary to use the cutting instrument : the anterior lip of the wound must be raised so as to observe the coraco-brachial muscle B, and the median nerve 3, which touch at its internal side. This nerve perceived, the artery 1 will be found at its posterior side. If, after having made an incision of the parts which cover the artery, we make an examination, proceeding from the anterior to the posterior part of the axilla, we easily arrive in the midst of the nerves which terminate the brachial plexus : an error may be here easily committed, when the radial and cubital nerves are as nearly as possible the same size as the median, if we mistake either of these nerves for the latter, we shall never arrive at the artery. The most simple proceeding then, is to follow the coraco-brachial muscle ; the first nerve which we perceive in proceeding backwards is the median, and the artery is at its posterior part. The cellular tissue, which fills the cavity of the axilla, being loose and easily broken, the insulation of the artery will be found very easy.

The ligature having been applied, and the wound dressed, the arm must be brought in contact with the trunk.

II. THE BRACHIAL ARTERY.

The brachial is the continuation of the axillary artery : it extends from the inferior edge of the tendon of the latissimus dorsi to half an inch below the humero-cubital articulation. The relations of this artery with the surrounding parts are very different, accordingly as it is examined in its two superior or its inferior third : in both parts it is only covered by skin and aponeurosis ; so that it is easy to ascertain the position of this vessel by the touch. As a general rule this precaution should never be neglected, and by no means in the case of the brachial artery, because it often exists as two branches and it is advantageous for the surgeon to know the state of the parts as far as possible before the operation, that he may be prepared for the consequences.

Below the axilla and in the middle of the arm, the brachial artery 7 corresponds, on its external side, with the internal side of the humerus, from which it is separated by the coraco-brachial muscle E, and after the insertion of that muscle, by the anterior brachial and biceps muscle D : its internal part is accompanied by the internal cutaneous nerve 10, and one or two brachial veins : more frequently the veins 8 are behind instead of being within. The anterior part of the brachial artery corresponds with the median nerve 9, and its posterior with the veins 8, the triceps muscle F, and the cubital nerve 11, which is always found separated four or five lines from this vessel. The cellular tissue uniting these different parts is soft and easily broken.

To perform the ligature of the brachial artery, the patient being laid, the arm separated from the trunk, and resting on its posterior and external side, the surgeon makes an incision, two or three lines behind the internal edge of the biceps, and parallel to the direction of that muscle : internally, from this edge, the first large nerve which is perceived is the median, the artery 7 touches its posterior side. When the precaution is not observed, if carrying the examination from the anterior to the posterior part of the arm, we may be easily led into error by the cubital nerve, which may be mistaken for the median, also by the brachial and basilic veins, which, from their size, may attract the attention of the operator. The artery, as before stated, is more posterior.

When the ligature, of which we are speaking, is to be performed above the middle of the arm, the internal edge of the biceps must not then be followed, but rather the internal edge of the coraco-brachial muscle will be a guide to the artery. If the examination be carried along the first of these muscles, the operator falls upon the deep groove which separates it from the second, and will in vain search for the artery.

III. TERMINATION OF THE BRACHIAL ARTERY.

The brachial artery may and frequently has been tied at the inferior part of the arm. In this region, it is situated more to the internal part of the arm, occupying its anterior part, and resting upon the anterior brachial muscle C ; and only covered by the aponeurotic expansion, arising from the internal edge of the tendon, the biceps B, and the skin : its relations with the median nerve are altogether changed ; the artery being external, and the nerve three or four lines internal. This change of position is from the decussation which takes place between these two organs, about two inches above the inner condile of the humerus : in the second ligature of the first figure of this plate, the commencement of this decussation is seen towards the inferior part of the wound. Two veins 2 generally accompany the artery, one external and the

other internal. Upon the aponeurotic plane, in the direction of the artery, we find the median basilic 6, and more externally the median cephalic vein 5.

In order to perform the ligature of the termination of the brachial artery, the fore-arm being extended, the position of the artery is indicated by a line which, taking the middle of the space separating the two condyles of the humerus, proceeds upward and inward to reach the internal edge of the biceps; the surgeon makes an incision, in this direction, of the skin for two inches, he must then ascertain the position of the sub-cutaneous veins, which having carefully done, he must insert the grooved director under the aponeurosis of the biceps, and to arrive upon the artery, divide it: before making his examination, and the necessary manipulations for insulating the artery, he must direct the fore-arm to be slightly flexed upon the arm, so that its separation from the surrounding parts will be more easily accomplished.

The communications between the arteries of the shoulder and those of the arm are so numerous, and so easily demonstrated, after the ligature of the termination of the axillary artery, that their description may be omitted. The same may also be done when treating of the ligature of the femoral below the profunda, and of the arteries of the leg.

Plate VIII.

Ligature of the Radial Artery.

Figure First.

I.

A—Olecranon.
B—Inferior extremity of the radius.
C—Inferior extremity of the ulna.
D—Muscle and tendon of the supinator radii longus.
E—Pronator radii teres.
F—Palmaris longus.

1—Radial artery. 2—Its two accompanying veins. 3—Radial nerve.

II.

G—Tendon of the supinator radii longus.
H—Tendon of the palmaris longus.
I—Flexor pollicis longus.

4—Radial artery. 5—Radial veins.

Figure Second.

III.

A—Projection of the inferior extremity of the ulna.
B—External side of the inferior extremity of the radius.
C—Tendon of the extensor carpi radialis longus.
D—Tendon of the extensor assis metacarpi pollicis.
E—Tendon of the extensor primi internodii pollicis.
F—Dorsal surface of the carpus.
G—Superior extremity of the second metacarpal bone.

6—Radial artery. 7—Veins accompanying it. 8—Sub-cutaneous vein.
9—Cutaneous branches of the radial nerve.

PL. VIII.

Fig. 1

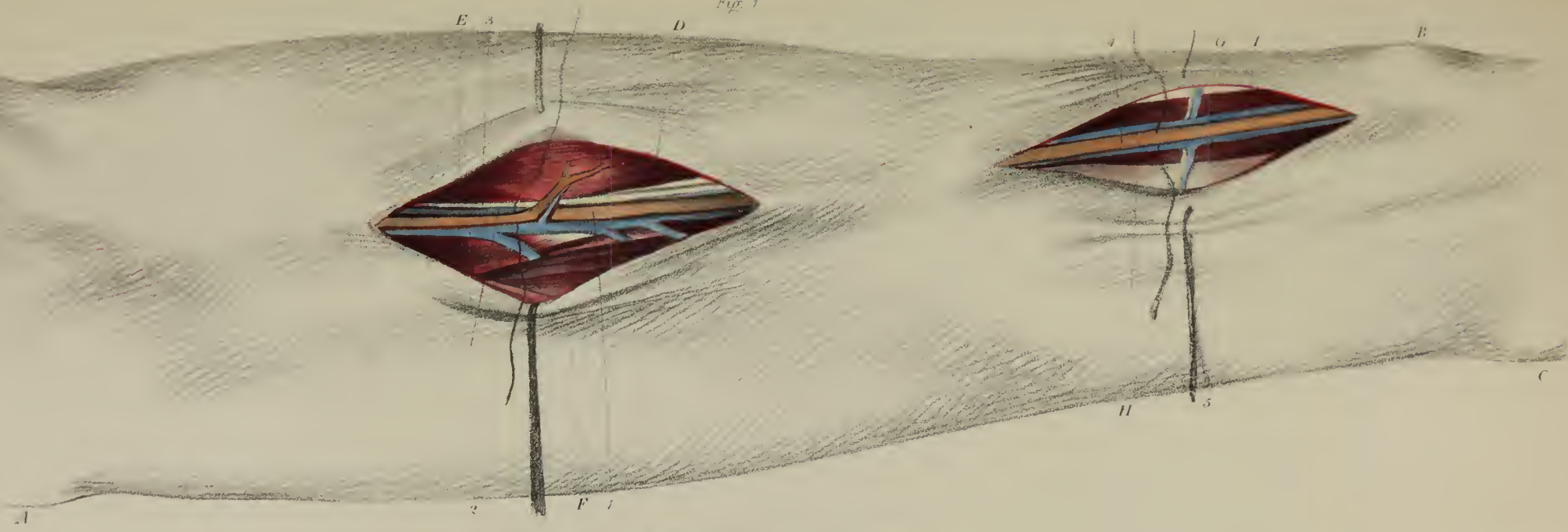
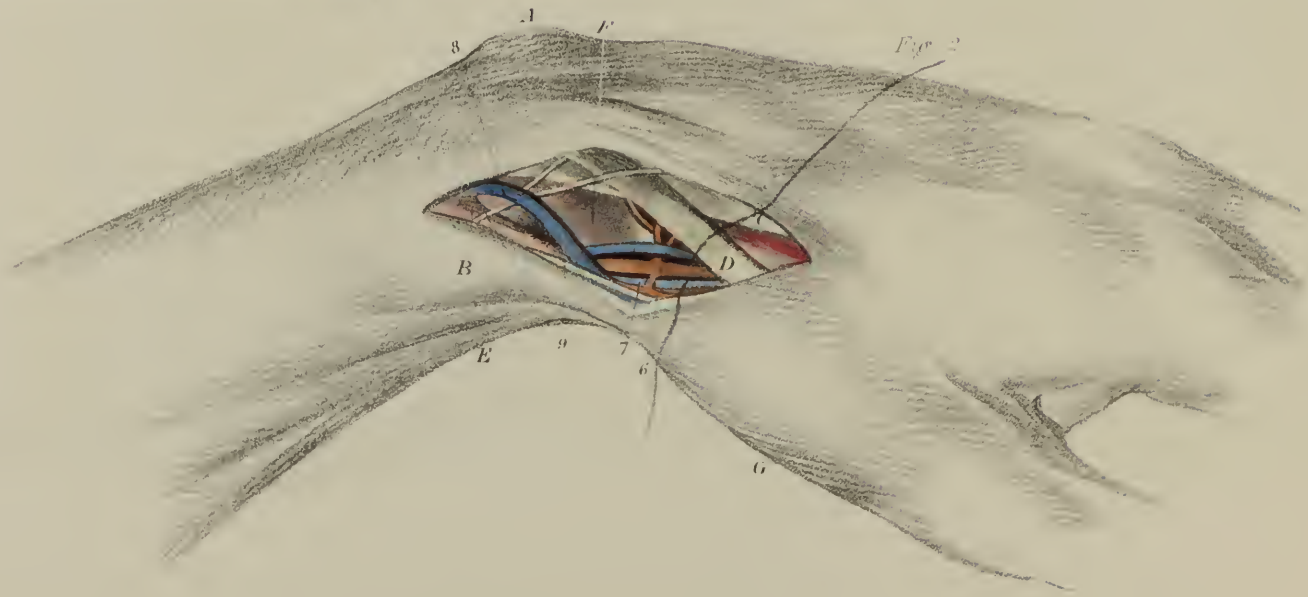


Fig. 2



R. Martin Lithog 124 High Holborn

I. THE RADIAL ARTERY.

The ligature of the radial and cubital arteries, ought not, I think, to be attempted at the superior part of the fore-arm, because it is totally impossible in a case of hæmorrhage, from a wound of the superior fourth or fifth part of the limb, to ascertain in a precise manner, the particular artery which has been wounded. In fact, in this region, the same lesion, if rather deep, may wound both of the principal arteries, or perhaps one, and with it the interosseous artery, and sometimes all these arteries together. The termination of the brachial artery, which, in some subjects, descends an inch below the articulation of the elbow, may be also opened by the same wound. The possible great uncertainty as to the precise vessel furnishing the hæmorrhage, ought, in this case, to induce the surgeon to perform the ligature of the termination of the brachial artery, rather than search for the artery, or arteries, which furnish the blood. There may, however, be a spontaneous aneurism of the radial artery, which, whilst small and circumscribed, would present those indications upon its course, that the ligature may be applied upon the superior part of the vessel: the other arteries are situated too deeply to enable, at so great a distance from the skin, an incipient aneurism to be distinguished. In this uncertainty the surgeon must avoid every operation of the fore-arm, and tie the brachial artery at its termination.

The radial is of smaller size, and throughout the whole of its course constantly more superficial than the cubital artery. It extends from the end of the brachial artery as far as the superior part of the first interosseous space of the metacarpus. In the fore-arm it follows the direction of an oblique line, which, extending from the middle of the bend of the arm, passes to the inner side of the styloid process of the radius B, to its posterior surface: it lays, superiorly, upon the supinator radii brevis, and the pronator radii teres muscle E; inferiorly upon the flexor digitorum sublimis, flexor policis, and the pronator quadratus: anteriorly, it is only covered by the skin and the aponeurosis of the arm; nevertheless, in that part of its course corresponding with the thick part of the supinator radii longus D, it is slightly covered by that muscle: by its external side it corresponds with the supinator radii longus in the superior part, but inferiorly, it is separated from it for the space of four or five lines: by its internal side it corresponds above with the pronator radii teres E, and below, with the palmiris longus muscle F. Besides the relations just mentioned, the radial artery is constantly accompanied by two veins 2, one internal and the other external to it: the radial nerve 3 has only relation with the superior part of this vessel, and is placed to its external side; below the middle of the fore-arm, the nerve separates entirely from it, to become sub-cutaneous and posterior.

To perform the ligature of the radial artery above the middle of the fore-arm, the limb being extended, and resting upon its dorsal surface, the surgeon placed to the outside, makes an incision at least two inches in length, and parallel with the internal edge of the supinator radii longus muscle. In order to find the edge of that muscle, it is sufficient to apply the fingers of the right hand upon the radial artery, as if to feel the pulse, and trace it towards the bend of the arm, by following the furrow which is bounded externally by the supinator radii longus, and internally, by the pronator radii teres, and the palmaris longus muscle. In this manner the intermuscular space which lodges the vessels is easily found. If the incision, however, is not made perfectly to correspond with this line, it will not be of much inconvenience: to remedy this fault it is sufficient to divide a few muscular fibres, to arrive at the artery, which is always found in the first intermuscular space we arrive at, in tracing from the external to the internal side of the fore-arm. The mobility of the skin upon the aponeurosis renders the examination of this space very easy; and on account of the simple incision, it will only be necessary to explore a surface of about an inch. The skin alone having been cut the surgeon searches, as we have said above, for the internal edge of the supinator radii longus muscle, and dividing the aponeurosis parallel with that muscle and slightly raising it, perceives the vessel placed immediately below. But before proceeding to insulate, in order to tie the artery he must open, upon the grooved director, the aponeurotic covering of the supinator radii longus muscle. This layer divided, the operation is easily terminated.

II. THE INFERIOR PART OF THE RADIAL ARTERY.

At the inferior part of the fore-arm the muscles which we have seen to surround by their fleshy bodies the upper portion of the radial artery, being only represented by their respective tendons, a large space is left between them, so that nothing can be easier than the ligature of the artery in this region. This artery 4 is accompanied, as in its superior part, by two veins 5, one internal and the other external to it: and covered by the aponeurosis and the skin. To perform this operation, an incision corresponding with the middle of the space which separates the tendons of the supinator radii longus, and the palmaris longus muscles, must be made to divide the skin; and a grooved director inserted under the aponeurosis, in order to divide it to the same extent as the skin. This done, the artery, with its accompanying veins, is seen; the insulation must be carefully done, so as not to wound the veins, and the ligature applied. It may be mentioned, however, that the rupture of a single vein, or its ligature, if it be small, does not occasion any real difficulty.

III. THE TERMINATION OF THE RADIAL ARTERY.

When the radial artery has arrived below the inferior part of the radius in descending, it turns from before backward, and from without inward, to arrive at the superior part of the first interosseous space. In its course this artery 6 runs along the external edge, and lays upon the posterior surface of the carpal bone F: it is covered by the tendons of the great abductor and small extensor muscles of the thumb E, and lower still by the tendon of the long extensor D. Between these tendons and the skin are seen the terminating filaments of the radial nerve 9, and one or two superficial venous branches 8, which, upon the dorsal surface of the hand, give origin to the radial veins: during the operation care must be taken to observe that the veins, and others which are situated much more deeply, have no relation with the artery.

For the ligature of the termination of the radial artery, the hand must be pronated and slightly flexed upon the fore-arm. The surgeon then makes an incision, which, from the external side of the styloid process of the radius, must be prolonged as far as the superior part of the space which separates the first from the second metacarpal bone, taking care only to divide the skin: this being done, he must carry to one side the subcutaneous veins 8, and divide such of the nervous filaments as may cross the direction of the incision: he then ascertains the position of the tendons of the long extensor D, and the short extensor of the thumb E, and between these tendons, and towards the most depending part of the carpus, divides the soft and thick kind of aponeurosis which fills this region. Under this, some flakes of fat are seen, which, if troublesome, from their size, must be extirpated: this fat being raised or taken away, we perceive upon the carpal bone a thin aponeurotic layer, through which the radial artery 6 and its accompanying veins 7 may be seen. This aponeurosis must be opened upon the grooved director, and the insulation of the artery becomes then very easy. In consequence of its deep position, in applying the thread, it will be more convenient to use the hafted hook, than any other instrument.

Plate IX.

Ligature of the Cubital Artery.

Figure First.

I.

A—Olecranon.
B—Internal condyle of the humerus.
C—Inferior extremity of the ulna.
D—Flexor digitorum sublimis elevated.
E—Flexor carpi ulnaris carried slightly inwards.
F—Flexor digitorum profundus.
G—Tendinous portion of the flexor sublimis.

1—Cubital artery. 2—Its accompanying veins. 3—Cubital nerve.

II.

H. H—Tendons of the flexor digitorum sublimis.
I—Tendon of the flexor carpi ulnaris.

4—Cubital artery. 5—Its accompanying veins. 6—Cubital nerve.

Figure Second.

III.

A—Projection formed by the os pisiforme.
B—Adductor minimi digiti.
C—Portion of the palmaris brevis : its superior part divided.

1—Cubital artery. 2—The posterior branch communicating with the deep palmar arch. 3—Veins which accompany the artery. 4—Cubital nerve, lying to the external side of the os pisiforme.

PL. IX

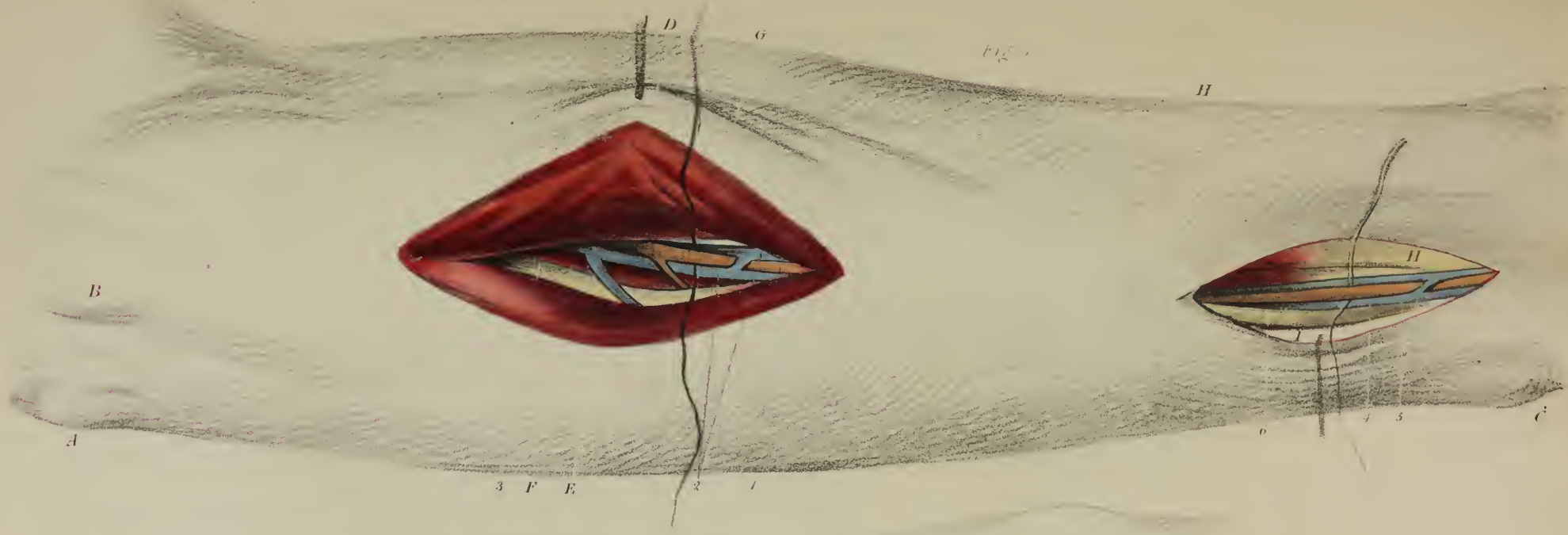
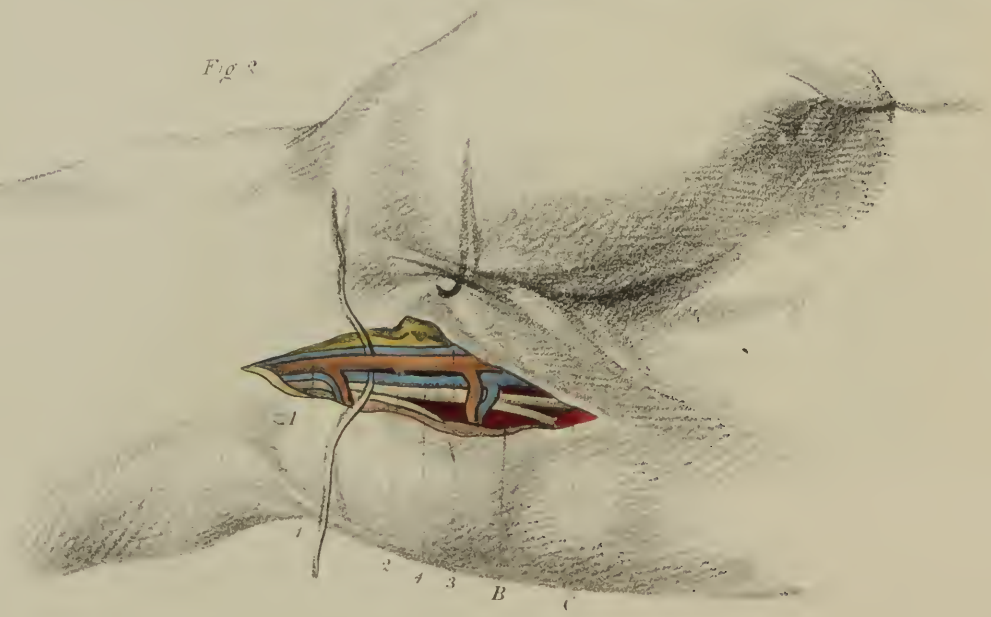


Fig 2



R. Morris, Lithog. 39 High Holb.

I. THE CUBITAL OR ULNAR ARTERY.

In hæmorrhages resulting from a wound of the superior part of the fore-arm, it is the position of the cubital artery which, especially, prevents the easy discovery of the particular artery which furnishes the blood. This artery being, in fact, placed much deeper than the radial, is found very near the common interosseous artery, to which it gives origin; and is generally covered by such thick muscles as to render it impossible, in a wound of the superior part of the fore-arm, to ascertain its state. If we are even certain that it is wounded, its position renders the success of its ligature much less sure, than that of the same operation performed upon the brachial artery. It results, therefore, that abjuring as we do this operation, when the disease is supposed to exist in the radial artery, which is much more superficial, we have stronger reasons for abstaining from it, when there is cause to suspect that the cubital artery is wounded or diseased.

The cubital artery commences at the middle and superior part of the fore-arm, and directs itself, in the first place, obliquely from above downward, and from without inward, towards the middle part of the fore-arm. From that point, as far as the internal part of the palm of the hand, where it terminates, it runs downward almost in a straight line. Throughout the whole length of the fore-arm it lays upon the flexor digitorum profundus muscle, and in the palm of the hand, upon the annular ligament. Anteriorly, it is covered at its upper part by the whole thickness of the muscles which are attached to the inner condyle of the humerus, viz. the pronator radii teres, palmaris longus et brevis, and the flexor digitorum sublimis laying before it. Below the middle of the fore-arm these muscles, as well as the flexor carpi ulnaris, become represented only by their tendons, so that the artery is found disengaged, and covered only by the skin and aponeurosis. Upon the annular ligament it is covered by the skin, adipose tissue, and superior fibres of the cutaneous palmar muscle. By its external side, the cubital artery is in relation with its vein 2 accompanying it throughout its whole course: by its internal, it corresponds with the other vein, which frequently communicates with the former, and with the cubital nerve 3, which throughout its course follows the internal side of the artery: superiorly, it is separated from it for some lines, but is in immediate contact, from the middle of the fore-arm.

When the brachial artery divides into two branches before its arrival at the bend of the arm, it very often happens that this variety will occasion others, in the position of the arteries of the fore-arm; which are almost always found to be situated more

superficially than ordinary: this disposition is especially remarkable in the cubital, which, in these cases, instead of presenting the relations which have been just pointed out, is placed immediately under the aponeurosis.

For the reasons before stated, the ligature of the cubital artery ought not to be attempted in the superior fifth of the fore-arm. There it is so deeply situated, and so nearly in the centre of the limb, that the operation would be very difficult; but after its arrival at the point of union of the superior fourth with the inferior three fourths of the limb, it is sufficiently near the internal edge as to be reached in its passage from within outward.

In order to perform this operation the fore-arm must be extended and laid upon its dorsal surface. The surgeon placed either to the inner or outside of the limb, searches for the tendon of the flexor carpi ulnaris, which is readily known at its inferior part; if the patient be very stout it is not so easy; in this case, the hand must be directed to be flexed and extended, and the wrist being compressed at the same time, the gliding of the tendon will be felt by the fingers. This done, he must trace from below upward, the furrow which separates the tendon I from that of the flexor digitorum sublimis H, and thus proceeding towards the internal condyle of the humerus the direction is indicated, in which the incision must be made. The surgeon, after having determined the position of the edge of the flexor carpi ulnaris, makes an incision of the skin, with the convex edge of a bistoury, parallel to that edge: he then searches for the first intermuscular space which can be found proceeding from the ulnar to the radial side of the arm. If the skin be very moveable, this is easily distinguished; so that if the first incision be badly directed it can be corrected, by means of the mobility of the skin; we could not, however, avail ourselves of this resource, had the skin, aponeurosis, and a certain portion of the muscular fibre, been cut at the same time. Having found the intermuscular line which is formed by the contact, and one superficial adhesion of the flexor carpi ulnaris E, the flexor digitorum sublimis D, the aponeurosis which unites them must be divided, and those muscles forcibly separated from each other. In order to facilitate the opening of the wound, it is recommended that the hand be slightly flexed upon the fore-arm, and the fore-arm upon the arm. In following the external surface of the flexor carpi ulnaris from within outward, we see, upon the same plane, first, the cubital nerve 3, the internal vein 2, and then the artery 1, with the other vein to its outside. At the superior angle of the wound, the nerve is separated from these vessels by a space which diminishes towards the inferior angle, until they become in immediate contact. These vessels having been exposed, the artery must be insulated, and the ligature made.

II. INFERIOR PART OF THE CUBITAL ARTERY.

At the inferior part of the fore-arm this operation becomes much easier. The two muscles which being in apposition superiorly, cover the artery 4, and its accompanying veins 5, are in this region separated from each other for the space of four or five lines; so that it is extremely easy to arrive at the artery. To accomplish this, an incision of the skin, must be made parallel to the tendon of the flexor carpi ulnaris I, but two or three lines external to it. Having divided the skin, the last named tendon must be found, and having inserted the grooved director under the aponeurosis, its division must be made to the same extent as the incision of the skin. The opening having been made, the tendon of the flexor carpi ulnaris I, the cubital nerve 6, and then the vessels are exposed to view: the artery 4 is placed between its two veins 5: it is easily insulated, and its ligature finished.

III. TERMINATION OF THE CUBITAL ARTERY.

In order to tie the cubital artery, at the superior part of the hypothenoid eminence, when it lays upon the annular ligament, an incision an inch and a half long must be made three or four lines to the outside of the os pisiforme A, dividing the skin, adipocellular tissue, and the superior fibres of the palmaris brevis muscle C. Frequently, after this first incision, the fat which has been forcibly compressed in the areolæ of the cellular tissue, escapes from those cells which have been opened, and completely fills the wound. In this case, the part must be extirpated, because, without this precaution, the termination of the operation would be tedious and painful. Having once taken away these flakes of fat, we perceive, to the outside and in contact with the os pisiforme, the cubital nerve 4, and beyond the nerve, the artery 1 surrounded by two veins 3, one to its internal and the other to its external side. After having insulated the artery, great care must be taken to place the ligature above the origin of its posterior branch 2, which goes, as before stated, to anastomose with the termination of the deep palmar arch. Without this precaution, we are constantly exposed to secondary hæmorrhage.

When the ligature of either the radial or cubital artery has been performed, for a wound, care must be taken to tie both ends of the vessel. Without this precaution, the blood flowing so freely and quickly, by means of the palmar arches, from one into the other, hæmorrhage will take place from the inferior extremity of the vessel almost immediately after the operation. In the case, where the ligature of the inferior end has been neglected, and a discharge of blood takes place, before proceeding to a fresh operation, it will be proper to try compression upon the inferior end of the diseased artery,

as well as upon the sound vessel: but if, after some time, the hæmmorrhage re-appears, we must not hesitate, immediately to apply the ligature. The inconveniences of this second operation are much less serious than those which would follow long continued pressure. In the case of an aneurism of an artery of the fore-arm, we tie at first, between the heart and the tumour, and use compression below: but if this compression becomes uneasy and painful it must be discontinued, and the ligature applied.

If a wound or an aneurism be situated upon the termination of the arteries of the fore-arm, and where it is impossible to use compression, or to tie the vessel below the wound, it must be done upon the superior end; first using compression, and if that is insufficient, the ligature of the sound artery.

When a deep wound penetrates into the palm of the hand and hæmorrhage ensues, as in these cases, many arteries have been opened, and it is difficult as well as very dangerous to proceed to search for the wounded arteries, on account of the complicated and important parts contained in the hand; both the radial and cubital arteries must then be compressed at the inferior part of the fore-arm, and their ligature effected, if the compression cannot be continued.

After this occurrence, I can state, without any doubt, that this double operation may be performed upon an adult man, without endangering the continuation of the circulation in the hand, to that extent so as to destroy its life: but this perhaps would not be the case if the operation were performed upon an old man. With this uncertainty, I think that when we have to treat a hæmorrhage of the palm of the hand upon a person of advanced age, the ligature must be applied as low as possible upon the radial and cubital arteries, so as to preserve upon one side, the dorsalis carpi, and dorsalis pollicis, etc.: and upon the other, the internal branches which arise from the cubital, before its passage to the external side of the os pisiforme.

Plate X.

Ligature of the External Iliac, and of the Crural below the Pubis.

The subject is inclined to the right side. The thigh rotated inward, a position unfavourable for the ligature of the external iliac, as well as of the femoral, but given to the body in order to render the drawing possible.

I.

A—Anterior and superior spine of the ilium.
B—Symphysis pubis.
C—Aponeurosis of the external oblique muscle.
D. D—Internal oblique muscle.
E. E—Transversalis muscle.
F—Iliac fossa.
G. G—Convolutions of the small intestine, enveloped by the peritoneum, the whole elevated and carried upward.
H—Fascia transversalis.

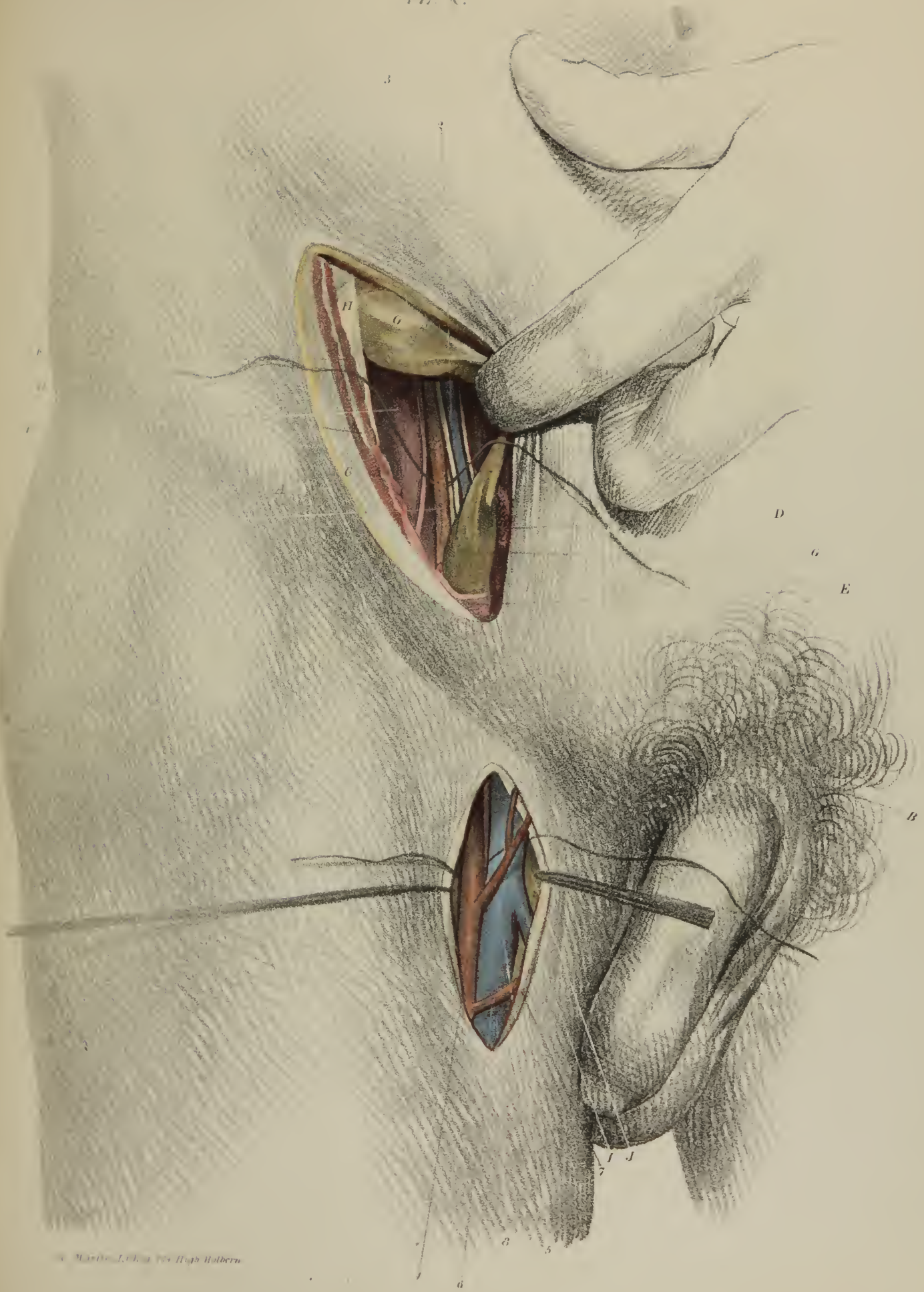
1—External iliac artery. 2—Anterior part of the iliac vein. 3—Nerves of the lumbar plexus.

II.

I—Superficial layer of the aponeurosis of the fascia lata.
J—Deep layer.

4—Crural artery. 5—Superficial epigastric. 6—External pudic artery. 7—End of the saphena vein. 8—Crural vein.

PL. X.



I. THE EXTERNAL ILIAC ARTERY.

The aorta having descended towards the inferior part of the lumbar region, divides into two trunks, which have been named the primitive iliac arteries. These, descending obliquely, are separated from each other opposite the sacro-iliac symphyses. Having arrived before these articulations they each divide into two branches; one deep, called the internal iliac or hypogastric; the other, larger, takes the name of femoral, and goes to be distributed entirely to the inferior extremity. The primitive iliac arteries vary in length from two to two and a half inches; they furnish no branches; the hypogastric arteries, immediately after their descent into the pelvis, divide, in a very variable manner, into a great number of branches, which are distributed to the organs within the true pelvis, and to the parietes of that cavity. Lastly, the external iliac arteries for about three inches, run along the superior outlet of the pelvis, placed to the inside of the prominence of the psoas and iliacus muscles; they do not at first give off any branches, but, having arrived opposite to the posterior edge of the pubis, they furnish the circumflexa ilii and the epigastric arteries. That part of the arterial system, passing along the superior outlet of the pelvis, from the termination of the aorta, as far as the pubis, is only very feebly connected with the parts with which it is in contact: it is accompanied by one single vein, and covered only by peritoneum, which forms a fold over it, in the same manner as over the umbilical vessels. The ureter passes before the termination of the primitive iliac, and the spermatic vessels before the external iliac. From these relations, it results, that the insulation of the iliac is much easier than that of the other arteries.

For a long time, aneurisms of the external iliac arteries, and of the superior parts of the crural were considered altogether beyond the resources of surgery: at least, for a long time, they were only treated by local topical applications. Science is indebted to Mr. *Abernethy*, a distinguished English surgeon, for the bold operation, by means of which, we are enabled to perform the ligature of the external iliac arteries; and, consequently, treat inguinal aneurisms with the same advantages as those of other parts of the body accessible to instruments. This operation and the success which crowned its third trial, has had such a powerful influence upon surgery, that, since that time, many surgeons in France, and other countries, have performed the ligature of others of the large arteries, which before had not been attempted. Thus the ligature of the primitive carotid artery, that of the subclavian within the scaleni muscles, of the hypogastric, and lastly, of the aorta itself, must, in our opinion, be regarded as the natural consequence of *Abernethy's* operation.

It has been stated that the external iliac artery 1 extends from the sacro-iliac symphysis, as far as the body of the pubis: it is accompanied by a vein 2, of the same name, situated to the interior and rather posterior part of the artery. Between these vessels, and sometimes entirely upon the artery, a small nervous branch 3 is found, arising from the lumbar plexus to pass to the superior and internal part of the thigh. More internal than the artery, a second nervous filament 3 is also seen, laying upon the psoas muscle F. The iliac artery and vein, and the accompanying nerves, are united together by means of cellular tissue, not very abundant, and easily torn. In middle aged persons these vessels descend directly along the prominence of the psoas and the aponeurosis which covers that muscle, to arrive upon the body of the pubis. On the contrary, in aged persons, it very often happens that the iliac artery descends into the true pelvis, forming many flexuosities before it ascends upon the pubis. The peritoneum G, G, passes before the vessels, which are only united together by a very thin cellular tissue, but which, however, is stronger than that which unites them to the superior outlet of the pelvis. The peritoneum, in ascending from the pelvis, after having covered the iliac vessels, lines the iliac fossa, and passing from behind forward, arrives upon the posterior surface of the abdominal muscles: the reflection of this membrane from the iliac fossa, towards the anterior parietes of the abdomen, passes below G, before the artery; and more above, the more the point of that reflection is removed from the artery, the more it is raised from it: so that, to arrive upon the vessels, the peritoneum must be separated, superiorly, for an extent of one or two inches, whilst inferiorly, it will scarcely require to be raised at all. Some intestinal convolutions, G, G, which are displaced along with the peritoneum, cover the iliac artery: lastly, more anteriorly, the different constituent parts of the abdominal parietes are found. It results, therefore, from this disposition of the parts, that, in order to expose the external iliac artery, the skin, the superficial fascia, the aponeurosis of the external oblique muscle, the internal oblique, and the transverse muscles, and the fascia transversalis must be cut, but the peritoneum must be carried aside: and we have seen how very easy it is to separate it from the iliac fossa as well as from the vessels.

When it is intended to perform the ligature of the external iliac artery, the patient must be laid upon the back, the pelvis a little inclined towards the healthy side, so that the intestinal folds may fall into the pelvis, causing less projection of the peritoneum in the bottom of the wound: the surgeon then makes an incision from three to four inches upon the abdominal parietes, its inferior extremity commencing eight or ten lines above the crural arch, and two inches to the outside of the spine of the pubis; this is continued obliquely upward and outward towards the crest of the ilium, terminating ten or twelve lines within the internal side of that crest. In giving that direction to the

incision, the abdominal parietes are less weakened, than if the incision had approached nearer the crural arch and the epigastric artery, and the spermatic cord are also avoided, being left to the inner side. The skin and the superficial fascia having been divided, there is generally a discharge of blood from the superficial epigastric artery: the ligature of that artery must be made, and the aponeurosis of the external oblique muscle then divided. In order to open the internal oblique and transverse muscles the grooved director must be used, to protect the parts which lay beneath: without that precaution, however dexterous the surgeon may be, it exposes the peritoneum to be opened, and the intestine wounded: that is more likely to happen during inspiration, when these organs are protruded outward, and in that manner are presented to the edge of the instrument. The whole of these muscles having been divided, to the same extent as the skin, the fascia transversalis must then be opened with great caution: but it is very frequently opened at the same time that the transverse muscle is divided. The peritoneum having been exposed, and the branches of the epigastric and the circumflexa ilii, which may have been cut during the incision of the muscles, having been tied, the operator lays aside the instruments, and uses his fingers alone to detach the peritoneum from the fascia iliaca, and to carry it from without inwards. Having arrived at the superior outlet of the pelvis, upon the prominence formed by the psoas muscle, the indicator finger of the right hand must be applied to that part, in order to feel for the pulsation of the artery: if it cannot be felt, the finger must be glided towards the pubis, where the pulsations of the artery can always be felt, because, whatever may be its position superiorly, it always terminates by arriving upon that bone. Having ascertained the situation of the vessel, an assistant must forcibly separate the lips of the wound, and at the same time depress the peritoneum, which has always a tendency to protrude. The operator then takes the hafted hook, and with it, and the other hand alone, separates the artery from the vein, carrying the latter towards the cavity of the pelvis, and gliding, at the same time, his armed hook under the artery, using the greatest care not to include within the ligature, the nervous filaments 3, which accompany the vessels.

After the ligature of the external iliac artery, the circulation is maintained in one part, by means of the numerous anastomoses which the branches of the hypogastric have with the arteries of the superior part of the thigh, and in the other, by the communications of the epigastric and the circumflex iliac with the internal mammary, the last intercostal and the lumbar arteries.

By slightly modifying the incision, which has been pointed out as the best for exposing the external iliac artery, it is also easy to arrive upon the internal iliac and the common iliac. For that purpose it is sufficient to make the incision, so that its inferior

and internal extremity corresponds to an inch or fifteen lines above Poupart's ligament, and that it should be less oblique, its superior extremity being more distant by some lines from the crest of the ilium: in this manner, after having divided the abdominal parietes, and detached the peritoneum from without inwards from the superior part of the iliac fossa, we easily arrive at the sacro-iliac symphysis, where the common iliac terminates and the hypogastric arises. The insulation and ligature of the former of these arteries is much easier to effect than that of the latter, which is found, immediately after its origin, surrounded by many veins which open into the vein of the same name; so that there is danger of rupturing some of these veins. The ureter which passes before that artery, occasions a yet greater difficulty, in that operation. The hypogastric has been once tied only, and with success, by Dr. *Stevens*. I do not know any case of the primitive iliac having been tied. I think, however, that that operation ought to be performed, if an aneurism should be situated upon the commencement of the external iliac, or that of the hypogastric artery. After this operation, the circulation is continued by means of the same branches as those which have been pointed out after the ligature of the external iliac, excepting those of the hypogastric of the affected side. But the intra pelvic branches of that artery have so large and so numerous anastomoses with the termination of the mesenteric and with the corresponding arteries of the opposite side, that, in a short time, they receive as much blood as they did before the ligature of their common trunk.

II. THE FEMORAL ARTERY BELOW THE PUBIS.

The femoral artery should never be tied upon the body of the pubis, or immediately below that bone, excepting a wound of the vessel in that place take place. In that case, the surgeon has no alternative, but to tie it above the wound: but if an aneurism exist at the superior part of the femoral, below the origin of the profunda, he would prefer tying it immediately above that artery than approach the body of the pubis. In the first case there would remain between the ligature and the superior collaterals (the epigastric and the circumflex iliac arteries) a space of from five to eight lines, which would permit the formation of a coagulum; whilst in the second, this would be impossible; and he could only calculate, for the success of the operation, upon the adhesion of the lips of the divided internal and middle membranes.

At its passage from underneath the crural arch, the femoral artery 4 occupies as nearly as possible the middle of the space which separates the anterior and superior spine of the ilium A, from the symphysis pubis B. In the female, on account of the much greater breadth of the pelvis, it is much nearer the symphysis than the spine of the ilium.

The artery is accompanied by the femoral vein 8 placed at its internal side. These two vessels are contained within an aponeurotic canal formed by the separation of the two layers of the fascia lata ; one layer passing behind the vessels to be continuous with the fascia iliaca ; the other, before, to be inserted into the aponeurosis of the external oblique muscle. The crural nerves, placed to the external side of the artery, but not contained within its sheath, are laid upon the united psoas and iliacus muscles, and bound to them by the layer of fascia lata which passes behind the vessels to line the iliac fossa. It results that we can arrive at the superior part of the femoral artery, expose and insulate it, without perceiving any nerve ; therefore, if we do see a nerve, we are in a wrong direction, being external to the sheath of the vessels, and must immediately return towards the superficial parts and pursue the examination two or three lines more to the interior. Upon the layer of fascia lata, which passes before the femoral artery and vein, we find an abundant cellular tissue, in which the lymphatic vessels and ganglia of the groin are contained ; over these, the fascia superficialis ; and, lastly, the skin. In stout persons between the skin and the superficial fascia, a large quantity of fat is found, in which the superficial epigastric 5 artery ramifies.

In order to perform the operation now under consideration, the patient must be laid upon the back, the thigh separated from the median line, and rotated outward. The surgeon makes an incision two inches in length, parallel to the direction of the artery. The skin and the superficial fascia having been cut, a grooved director must be inserted under the superficial layer of the fascia lata, and that aponeurosis divided to the same extent as the incision of the skin : this done, the lips of the wound must be separated by an assistant, and the artery is then easily exposed : the vein, which is much larger than the artery, is also easily seen : the artery once exposed, nothing can be more simple than its insulation, and consequently the termination of the operation.

Plate XI.

Ligature of the Femoral Artery.

I

A—Middle part of the space which separates the symphysis pubis from the anterior and superior spine of the ilium.
B—Internal condyle of the femur.
C—Patella.
D. D. D—Projection formed by the sartorius muscle.
E—Sartorius muscle raised.
F—Anterior surface of the abductor longus muscle.

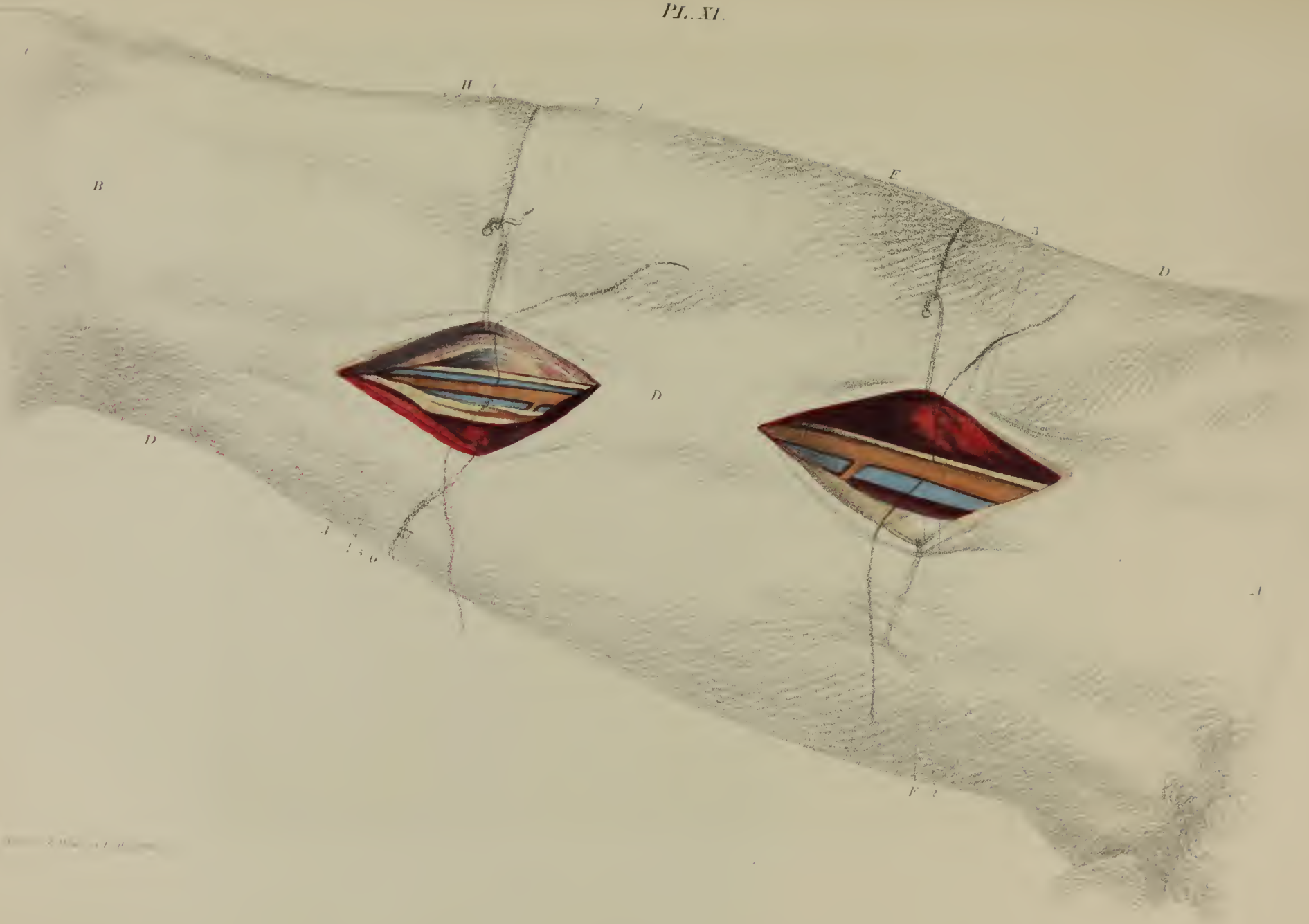
1—Crural artery. 2—Crural vein. 3—Saphenus nerve.

II.

G—External edge of the sartorius muscle, drawn backward.
H—Vastus internus muscle.
I—Tendon of the adductor magnus muscle.
J—Edges of the section of the aponeurosis, which unites the tendon of the adductor magnus to the vastus internus.

4—Crural artery. 5—Crural vein. 6—Small crural vein external to the artery. 7—Saphenus nerve.

PL. XI.



I. SUPERIOR PART OF THE FEMORAL ARTERY.

The femoral artery extends from the termination of the external iliac upon the body of the pubis, as far as the superior part of the popliteal space. It runs obliquely from above downward, from before backward, and from without inward, from its origin to its termination: that is, to the point of union of the superior three fourths with the inferior fourth of the thigh. It follows as nearly as possible, in the language of anatomists, a line drawn from the middle of the space which separates the symphysis pubis from the anterior and superior spine of the ilium, and terminating behind, in the middle of the space between the two condyles of the femur. The femoral vein accompanies the artery throughout the whole course, and is found, superiorly, at its internal side (see plate X.); but two or three inches below the pubis, it is placed to its posterior side, and keeps that position to its termination 1, 2, 4 and 5. The great saphenus nerve 3, 7, separates from the crural nerves, pierces the external wall of the aponeurotic canal of the vessels, and about two or three inches below the pubis becomes placed to the external side, and a little anterior of the femoral artery, and continues with it till its termination in the popliteal. Posteriorly and superiorly, the femoral artery is in contact with the body of the pubis and with the mass common to the psoas, iliacus, and pectineal muscles; inferiorly, immediately, with the vein that accompanies it, and mediately, with the adductor muscles. Anteriorly, it is covered, above, as we have already seen, by the different fascia of the groin, and the lymphatic ganglia; below, independently of its aponeurotic envelopes, it is also covered by the sartorius muscle E, G. Its external side corresponds, above, with the psoas and iliacus, below, for a short space with the sartorius, and then, with the vastus internus.

The femoral artery can be tied in every point of its course. Nevertheless, when the disease does not precisely indicate the part where the operation must be performed; the surgeon will not be indifferent in making choice of one region rather than another. We have already seen in the preceding plate, the inconveniences and danger which may follow this operation when performed a short distance below the pubis. This danger is yet more to be dreaded, if the ligature be applied immediately below the common muscular branch. In a case of wound of the superficial femoral some lines below the origin of the profunda; I think, after having tied the first of these vessels above and below the wound, the surgeon should also, in order to avoid hæmorrhage from the separation of the ligature, apply a ligature upon the second, or upon the termination of the common femoral artery. In this manner we have the advantage of obliterating the large collaterals, which, if not effected, would inevitably prevent the

formation of the coagulum. The ligature of the inferior part of the femoral artery is rather difficult on account of the narrowness of the canal which contains it: which renders its insulation much more difficult than in any other part of its course. And, if we consider that by thus operating, we cannot preserve any more of the important collateral branches for the continuance of the circulation, than when the operation is performed some inches from the origin of the profunda, we shall acknowledge, I think, the propriety of the advice given by *Scarpa*, that, whenever a disease of the inferior part of the crural or the popliteal requires the ligature of the principal artery of the thigh, that operation must be performed in the point of union of the superior third with the inferior two-thirds of the limb. M. *Dupuytren* at the Hôtel Dieu, and M. *Roux*, at la Charité, have also performed operations in that situation, for diseases of the arteries of the leg, with success.

The inferior part of the upper third of the thigh, is the situation which is to be chosen, when it is intended to tie the crural artery; the sartorius muscle D, D, D, must, in the first place, be found, and an incision made of the skin for three inches parallel to its internal edge. The inferior extremity of this incision must correspond with the point where the sartorius is in contact with the adductor longus F, and be prolonged obliquely upward and outward towards the superior part of the thigh. In making this incision, care must be taken to avoid the saphena vein, which, in this situation, corresponds with the sartorius muscle. The skin and aponeurosis having been divided, the surgeon must search for the sartorius, which is easily known by the direction of its fibres running downward and inward. Its internal edge E, must then be carried outward. This slight displacement exposes the sheath of the vessels; so that the section of any portion of that muscle is unnecessary, as some practitioners direct. Under the sartorius is found the deep layer of the fascia lata which forms the anterior wall of the sheath of the vessels. This aponeurotic layer must be taken hold of by the forceps, and a small opening made into it by the flat edge of the bistoury, so as to allow the insertion of the grooved director upon which this sheath must be divided to the same extent as the incision of the skin. This done, the surgeon will no longer use the cutting instruments: the artery 1 must be exposed; and it then only remains to surround it with the thread, which must be done by slightly displacing the artery by the dissecting forceps and the blunt hook by which the thread must be passed round the vessel. During these manipulations, care must be taken not to wound the crural vein 2, behind, nor to pinch the saphena nerve 3, to the outside.

II. INFERIOR PART OF THE FEMORAL ARTERY.

In the operation last described, it has been said, that the sartorius muscle must be carried to the outside, because the artery is nearer its internal than external edge: but if it be intended to apply the ligature at the point where the sartorius covers the artery entirely, it may be carried to either side; but when it is necessary to tie the artery below the middle of the thigh, the sartorius must then, be always carried from without inward.

From what has already been said of the situation and relations of the femoral artery at its inferior part, we may foresee the difficulties which its ligature in that situation must present. The aponeurotic canal which contains it, is in fact smaller than superiorly; and formed, not of a thin aponeurosis, but rather of a strong fibrous expansion J, which passes from the tendon of the adductor magnus I, to join the vastus internus muscle. It results, therefore, that the artery 4 is strongly united to the vein 5, and the nerve 7 which accompany it: these two latter organs preserve almost the same relations with the artery as in the middle part of the thigh, the vein being behind and the nerve before and to the outside. It sometimes happens in this region, that the crural vein is accompanied by another smaller vein, which is generally placed between the artery and the nerve, though occasionally, entirely before the artery. Upon the subject from which this plate was taken this variety existed, the secondary vein 6 being to the outside.

In a wound of the inferior part of the femoral artery, and when it is intended to apply the ligature, the limb being separated from the trunk and slightly flexed, the surgeon placed to its outside, must find the external edge of the sartorius muscle by the knowledge he has of the general direction of that muscle. In every case, if we do not arrive precisely upon the edge of that muscle, it is easy to correct the fault, by carrying the lips of the divided skin, a few lines inward or outward accordingly as we have deviated in either direction. It is important, after the incision of the skin obliquely from above downward, that we find the external edge of the sartorius, which must always serve as the guide to arrive at the artery. The skin and aponeurosis having been cut for three or four inches, and the position of the sartorius muscle G ascertained, its external edge must be carried inward and downward: we then see the internal surface of the vastus internus H, and gliding the finger from before backward upon this muscle, fall upon the tendon of the adductor magnus I. Between these two parts, is a slight depression which seems to widen from its base, forward; this is the canal of the vessels. Frequently one or two arterial branches are seen issuing from this canal to be distributed either to the sartorius or the skin. By applying the indicator finger rather firmly between the tendon of the adductor magnus and the vastus internus, the pulsations of the artery can be very distinctly felt. After having separated the lips of the

THE POPLITEAL ARTERY.

The situation of the popliteal artery in the deepest part of the ham renders its ligature extremely difficult; therefore, since the treatment of aneurism by opening the sac has been abandoned, this operation has seldom been performed. I think it ought only to be performed when a copious hæmorrhage follows a large wound of the popliteal space, where it would only be necessary to dilate the lips of the wound and proceed to the examination and ligature of the wounded artery: but if the hæmorrhage has been caused by a simple puncture, and it would consequently be necessary to divide the parts which cover the vessel in order to expose it, it would be more advantageous to tie the femoral artery above its middle part, than to try a tedious and painful operation: and which on account of these difficulties would render the patient more liable to consecutive hæmorrhage from the suppuration, than in ligatures in general. In the case of a wound or an aneurism situated upon the superior part of the arteries of the leg, and where it cannot be precisely ascertained which is the diseased trunk, we must avoid the popliteal and prefer tying the femoral artery in its best situation. This would also be proper when an aneurism exists upon the trunk of the popliteal artery. It is probable that had the celebrated *Desault* not applied the ligature immediately above the tumour, when he, the first, revived the method of *Guilemeau* for the treatment of aneurism, his operation would have been completely successful. The example, however, of J. *Hunter*, who about the same time, tied the crural artery in its passage within the aponeurotic canal formed by the vastus internus and the adductor magnus, although an improvement, is not the best to be adopted, on account of the very great difficulties which that operation presents. These difficulties have been considered under the preceding plate.

From what has been said, it appears that the cases in which the ligature of the popliteal artery is necessary, are extremely rare: and that which follows will, I think, justify the opinion which has been given of the difficulties of this operation.

The popliteal 1 is the continuation of the femoral artery:* it extends from the supe-

* I shall here speak of an anatomical variety of the greatest importance, and one, of which the annals of the science do not afford any example: it was found by my colleague M. *Eugene Caillard*, prosector of the Amphitheatre of the Hospitals.

Upon a female of middle stature, stout, and of regular proportions, the primitive iliac artery of the right side, having arrived at the sacro-iliac symphysis divided, as is ordinary, into two branches, an anterior and posterior. Contrary to the general rule, the former was much smaller than the latter: it represented the external iliac artery, and having passed out of the abdomen gave origin to the epigastric and circumflex iliac artery. Below the crural arch it gave off, internally and externally, the two circumflex arteries, and inferiorly, the perforating branches; it was then prolonged in the form of a slender branch along the vastus internus muscle, as far as the articulation of the knee, where it terminated by anastomosing with the articular arteries.

rior part of the inferior fourth of the femur, as far as the lower edge of the popliteal muscle: it occupies the bottom of the region which has been named the popliteal space. This space is bounded superiorly, by the semi-membranosus C, and semi-tendinosus, sartorius, gracilis, and biceps flexor cruris muscle D: laterally, by the condyles of the femur: and inferiorly, by the gastrocnemii E, and plantaris F. The artery is in immediate contact with the femur, the tibio-femoral articulation G, and the posterior surface of the popliteal muscle: its posterior side is covered by its accompanying vein 2: but to the internal side the artery 1 projects a little from the vein so as to be rather nearer than the vein to the internal condyle. One or two articular veins, and sometimes a greater number, surround the artery in passing to open into the popliteal vein; so that it is difficult to separate these two vessels, without running great risk of wounding some of the veins just mentioned. Three or four lines more posterior and a little to the outside, we find the sciatic nerve 4, and lastly, the external saphena vein 3, which runs to open into the popliteal in a point more or less above. The whole of these parts which have been enumerated, are surrounded by a very abundant fatty cellular tissue, containing three or four lymphatic ganglia; an aponeurosis and the skin envelope the whole.

From this description it is seen, that the superficial femoral did not exist, nor any branch descend from the internal part of the thigh into the ham.

The second branch of the primitive iliac, the hypogastric, in this subject, was more than twice the size of the external iliac: descending into the pelvis it gave origin, as ordinary, to the gluteal, ileo-lumbar, obturator, vesical, uterine, internal pudic arteries, etc.: but on account of its enormous size was not exhausted by giving origin to all these branches; there still remained a principal trunk as large as the femoral, occupying the position of the ischiatic artery, and which, as is generally the case, with that artery, passed out of the pelvis between the pyramidal muscle and the small sacro-sciatic ligament. Having escaped from the pelvis, it gave off, like the ordinary sciatic, some branches to the exterior parts of that cavity, and then descended along with the great sciatic nerve, as far as the popliteal space, where it assumed the situation of the popliteal artery and furnished all the articular branches; and, at the superior part of the leg, terminated by dividing into the anterior and posterior tibial and peroneal arteries.

By this distribution of the arteries of the thigh, it is seen, that the external iliac, after having left the pelvis, assumed the position of the profunda supplying the branches which ordinarily arise from that artery; that, the superficial femoral was a branch of the hypogastric; and that, by reason of the great difference in its origin, the position of that artery was totally changed; instead of following the anterior and interior part of the thigh, it occupied its posterior part.

This singular anatomical variety would have led the surgeon into a strange embarrassment, if the woman had had a disease of the popliteal artery, or if amputation of the thigh had been performed: in this case, compression upon or below the pubis, of the artery which occupied the place of the femoral would not have commanded the flow of the blood.

This anormal disposition would have been very fortunate, if there had existed an inguinal aneurism, or if the woman had been wounded upon the termination of the external iliac. In either case, that artery might have been tied in its middle part without any fear of gangrene of the limb supervening; however old the patient, the blood would still have maintained a very large course to circulate in the limb.

The specimen preserved by M. *Caillard*, is deposited in the Museum of the Amphitheatre.

In order to expose the popliteal artery, the patient must be laid upon the belly, and the leg extended upon the thigh: the surgeon having ascertained by the touch, the depression which behind, indicates the popliteal space, makes an incision along that space, which, on account of the depth to which he must penetrate, should at least be four or five inches in length: having divided the skin, he must open the aponeurosis upon the grooved director, taking care not to wound the external saphena vein 3, which sometimes runs the whole length of the popliteal space before it terminates. Having opened the aponeurosis to the same extent as the skin, the surgeon directs an assistant slightly to flex the leg upon the thigh; he must then separate the lips of the wound, and search for the sciatic nerve 4 in the midst of the cellular tissue, and having found this nerve, he proceeds deeper and a little inward; the vein 2 presents itself first, and then, the artery 1, which, adherent by its anterior side, projects rather inward from the vein: so that it is much easier to separate these two vessels, by going from that side rather than from the external, In separating the vein from the artery, care must be taken not to tear the articular veins. Although these vessels are so small, yet if opened, they will furnish a great quantity of blood, from the proximity of their termination in the popliteal vein. The same attention must also be paid, not to rupture the articular arteries. The artery being separated from the vein, the hafted needle is the best conductor which can be used for surrounding it with the thread.

After the ligature of the popliteal artery, the blood is carried from the parts above the ligature to those which are below, by means of the anastomoses of the superior articular with the inferior articular arteries; the first, receive it from the popliteal itself, if the ligature has been applied below their origin, or from the arteries of the thigh, if the ligature was placed above their origin.

I. THE SUPERIOR PART OF THE ANTERIOR TIBIAL ARTERY.

When the popliteal artery has arrived at the superior part of the leg, and has passed between the inferior edge of the popliteal muscle, and the aponeurotic arch formed by the superior edge of the soleus, it gives off, from its anterior part, a branch which traverses the interosseous ligament in order to descend upon its anterior surface, under the name of the anterior tibial artery: the popliteal artery soon after terminates by dividing into two branches, which take the names of posterior tibial and peroneal arteries. The manner in which the popliteal terminates presents some differences, relative to the length of the trunk common to the peroneal and posterior tibial arteries; so that the origin of these two arteries may take place at a greater or less distance from the soleus: on the contrary, the origin of the anterior tibial never varies; it always arises opposite the superior edge of the soleus muscle. Immediately after its origin, it traverses the interosseous ligament by passing between the two portions of the tibialis posticus muscle. Having arrived before the interosseous ligament, it descends upon its anterior surface as far as the inferior part of the superior two-thirds of the leg, in the remainder of its length lays upon the internal and anterior part of the tibia, and afterwards terminates opposite the tibio-tarsal articulation. In the whole of its course, the anterior tibial artery, 1, 4, is accompanied by two veins, 2, 5: one to the inner, and the other to the outer side. These veins generally have communicating branches from each other, which pass sometimes before or behind the artery. This small packet of vessels is accompanied by a nerve, 3, 6, which is furnished by the sciatic; it is the anterior tibial nerve: its relative position with the vessels is different, accordingly as it is considered in the superior or inferior part of the leg: superiorly, it lays to the outside, and inferiorly, to the inner side. This change of position takes place in the middle part of the limb, where it crosses very obliquely before the vessels. I designedly insist, as I have always done, upon the relations of the nerves with the vessels, because, from their whiteness they are generally the part which is most easily seen when the sponge has been passed to the bottom of a bleeding wound: and having once determined the position of one organ, the relations of which with the surrounding parts are understood, it is much easier to arrive upon the organ of which we are in search. The veins and nerve last mentioned, like the artery, lay upon the interosseous ligament at the superior part of the leg, and upon the tibia at its inferior part. The whole of these organs, by their internal side, are in relation with the tibialis anticus muscle, F, I, and by their external side, with the extensor communis G, in the superior fourth of the leg, and the extensor pollicis proprius H, J, in the inferior three-fourths: anteriorly, they are covered, by these different muscles, which meet in contact with each other before them.

It results from this last disposition, that the anterior tibial vessels are deeply situated at their superior part, because of the thickness of the muscles, but inferiorly, are more superficial on account of the muscles being only represented by their tendons; lastly, the aponeurosis of the leg and the skin envelope the whole.

The cases in which we may be called upon to apply the ligature of the anterior tibial artery, are very rare. This operation ought never to be attempted at the superior part of the leg; the thick muscles which cover the vessels being, in this region, included between the fibula and the tibia, in such a manner that it is impossible to separate the lips of the wound; it is, moreover, very difficult, except in the case of a circumscribed aneurism, to ascertain with sufficient precision, the nature of the disease, so as to decide upon the performance of so laborious an operation. In fact, a wound of the superior part of the leg, after having opened the anterior tibial artery, may traverse the interosseous ligament, and divide the termination of the popliteal or the commencement of the posterior tibial and peroneal; or the wounding instrument may have even glided by the side of the anterior tibial artery, and have only wounded the arteries of the posterior region. Lower down, this complication of wounds of the leg are less to be feared; the peroneal only can be divided at the same time as the tibial; and yet, it may happen, that the instrument may penetrate very obliquely from before, backward, and from within, outward.

In order to perform this operation, the patient must be laid with the affected leg resting upon its posterior part. The surgeon, placed to the outside of the limb, takes hold of the foot with one hand, and applies the four fingers of the other upon the inferior part of the spine of the tibia; he then moves the foot in flexion and extension, in order to ascertain the situation of the tendon of the tibialis anticus muscle D, which is the first, in passing from the tibia to the fibula. This tendon found, he must place the fingers on its external side, and by continuing the motions of the foot, and passing the hand upward, he easily perceives the intermuscular line which separates this muscle from the extensor proprius, below, and the extensor communis above: it is in the direction of this line that the incision of the skin must be made. Upon thin subjects, the motion of the foot is, alone, sufficient to indicate this muscular interstice. In many cases the incision may be a few lines too much either within or without, but this, the operator will easily remedy, if he has taken the precaution, by the first incision, to divide the skin alone. After having opened the skin, he must open the aponeurosis of the leg in the same direction: but, here, one single incision will not be sufficient, he must insinuate the bistoury held horizontally under the lips of the aponeurosis and divide them into two equal parts in the form of a crucial incision. The vessels are situated so deeply, that it is superfluous to use the grooved director in making these

different incisions. After that, the surgeon must apply the indicator finger of the right hand upon the tibialis anticus, and by gliding it from within outward, press upon that muscle. In this manner he is sure to fall into the first intermuscular space; whilst by using the cutting instrument in order to arrive at it, an artificial rout may be easily made, which is totally impossible by following the method here pointed out. As soon as the muscular interstice is discovered, the assistants, with blunt hooks, must separate the edges, and the surgeon having sponged the bottom of the wound, perceives the artery 1, which is surrounded by two veins 2. It is sometimes extremely difficult to separate these vessels from each other; the nerve 3, is placed to the outside of all the vessels. In order to pass the thread round the artery, a hafted hook with a very small curvature must be used.

II. THE INFERIOR PART OF THE ANTERIOR TIBIAL ARTERY.

Below the middle part of the leg, the ligature of the anterior tibial artery is, as before said, much more easily performed than above. The artery having left the interosseous ligament, lays upon the tibia, and the muscles which cover it are not so thick as above. The surgeon, after having recognised (by proceeding as we have already pointed out) the crest of the tibia, and then the external side of the tendon of the tibialis anticus muscle, makes an oblique incision from above downward, parallel to that side of the tendon. Having divided the skin and opened the aponeurosis crucially, the indicator finger must be carried under the internal lip of the wound, to search for the external side of the first tendon, which is found in going from the tibia towards the fibula. Without this precaution, if it is carried directly from the superficial to the deep parts, we may be led into error, and fall between the extensor proprius and the extensor communis, or perhaps between the different tendinous fasciculi of the last muscle. After having separated the tibialis anticus I from the extensor pollicis proprius J, the first thing which is seen is the anterior tibial nerve 6, then the tibial vessels, the artery 4, between its accompanying veins 5, one on either side. Here the insulation of the artery is much easier than above, on account of the wound not being so deep, and the facility with which its lips can be separated by slightly flexing the foot upon the leg. The passage of the thread around the artery is also very easy.

If the anterior tibial artery is tied in its middle part, the nerve will be found situated obliquely before the vessels, for the extent of an inch. The extensor proprius muscle which, although not yet so large as to appear upon the superficies of the leg is, however, sufficiently so as to form with the tibialis anticus a rather deep furrow to lodge the vessels, may more easily deceive the operator than in any other part of its course.

The application of the ligature of the tibial, too near the tibio-tarsal articulation, exposes the sheaths of the tendons of the extensor muscles of the foot to the risk of inflammation; which is a sufficient cause for abstaining from the performance of that operation.

III. THE PEDAL ARTERY.

THE anterior tibial artery having arrived before the tibio-tarsal articulation, and attained the dorsal surface of the foot, takes the name of pedal artery, which it preserves as far as the posterior part of the first interosseal space, where it terminates by dipping down towards the sole of the foot, to anastomose with the plantar arch: it is therefore scarcely three inches in length. This artery 1, lays immediately upon the dorsal surface of the tarsal bones; it is accompanied by two veins 2, which are sometimes very small, and by a nervous filament 3, which is situated to the outside. These different organs placed side by side are united together by a very compact cellular tissue. This disposition is very remarkable, in those persons who have worn strait and hard boots, or wooden shoes. Upon the plane formed by the vessels, we find a layer of cellular tissue having an aponeurotic appearance. Upon this layer, we find, to the inside, the tendon of the extensor proprius C, and to the outside, that of the extensor brevis going to the great toe; more superficially than those tendons, we find the aponeurosis of the dorsum of the foot, and the skin.

The cases in which the ligature of the pedal artery is necessary, are very rare: the vessel being found in the conditions so favourable for compression, that it almost always succeeds. However, it may be mentioned, that there are cases in which the patients cannot bear it, and others, where it has occasioned very severe accidents. In two cases in which long-continued compression had been applied to this artery, under Professor *Boyer*, the patients lost their lives.

To perform this operation, an incision must be made of the skin, for an inch or fifteen lines, the anterior extremity corresponding to the posterior part of the first interosseal space, and directed obliquely backward, to terminate at the middle part of the space which separates the two malleoli. After having divided the skin and the dorsal aponeurosis of the foot, the tendon of the extensor brevis muscle D, must be found; the artery 1 being placed before this tendon and that of the extensor proprius C; sometimes it is found more external, under the first tendon of the extensor brevis, so that it would be much easier to tie it at the out rather than the innerside of that bundle of tendons. Having displaced the tendon of the extensor brevis, the fibro-cellular layer which covers the vessels must be divided upon the grooved director, so

that the artery may be insulated, and its ligature accomplished, taking care not to include the nervous filament which accompanies it.

Occasionally the pedal artery is entirely wanting; or it is only represented by a very small branch; in these cases, the anterior tibial spends itself in furnishing the dorsal branches of the tarsus and metatarsus.

Plate XIV.

Ligature of the Posterior Tibial Artery.

Figure First.

I.

A—Internal condyle of the tibia.
B—Internal malleolus.
C. C—Internal edge of the tibia.
D. D—Aponeurosis of the leg.
E. E—Soleus muscle.
F. F—Aponeurosis of the anterior surface of the soleus, inserted with this muscle into the internal edge of the tibia.
&—Vena saphena.

1—Posterior tibial artery. 2—Its accompanying veins. 3. Posterior tibial nerve.

II.

G—Flexor digitorum communis muscle and its tendon.
H. H—Deep aponeurosis of the leg.

4—Posterior tibial artery. 5—Its accompanying veins. 6—Posterior tibial nerve.

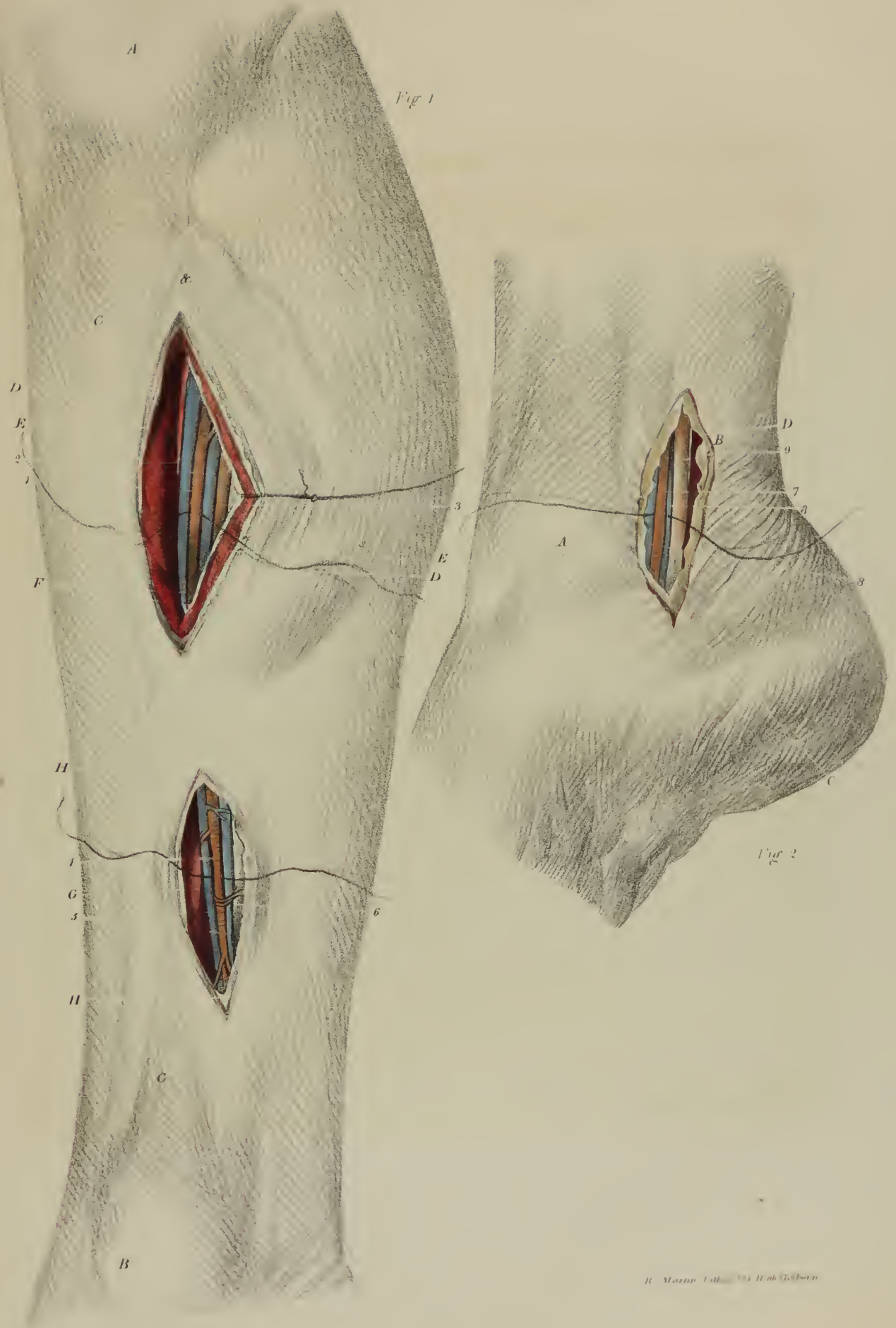
Figure Second.

III.

A—Posterior edge of the internal malleolus.
B—Internal side of the tendo Achillis.
C—Deep aponeurosis of the leg, very thick in this place.
D—Tendons of the flexor pollicis longus muscle.

7—Posterior tibial artery. 8. 8—Accompanying veins. 9—Posterior tibial nerve.

PL. XIV.



I. THE SUPERIOR PART OF THE POSTERIOR TIBIAL ARTERY.

It has already been said, under the preceding plate, that the posterior tibial artery arises much lower than the anterior tibial, and from a terminating trunk of the popliteal, which is common to it and the peroneal artery. It results, therefore, that the posterior tibial takes its origin from eight to ten lines and sometimes an inch lower than the anterior. This artery 1, 4, 7, extends from the inferior part of the superior fifth of the leg as far as the arch of the calcaneum where it terminates by dividing into the external and internal plantar arteries; it lays upon the muscles of the deep layer of the leg, principally upon the tibialis posticus and the flexor digitorum communis. Two veins 2, 5, 8, 8 very large in old persons, are placed one on either side of the artery; the posterior tibial nerve 3, 6, 9, is always found at the outside of the vessels; and does not, like the anterior tibial nerve, change its relations with the vessels accordingly as it occupies the superior or inferior part of the leg. The vessels and nerve are bound to the posterior surface of the deep layer of muscles, by an aponeurosis which is thin, superiorly, but gradually increases in thickness as far as the posterior annular ligament of the leg, with the superior edge of which it is continuous above. This aponeurosis, as well as the vessels, are covered by the gastrocnemii muscles and the superficial aponeurosis of the leg; inferiorly they are only covered by this aponeurosis and the skin. This difference is produced by the disproportion of breadth which exists betwen the superior and the inferior part of the muscles of the superficial layer of the leg; superiorly they are broad and thick; inferiorly, they are only represented by the tendo Achillis. The gastrocnemius muscle placed superficially and not having any relation with the bone of the leg, will not require particular consideration. But this is not the case with the soleus, which is in contact with the vessels, and attached to the tibia and fibula. In the superior half of the leg the soleus covers the posterior tibial vessels, and is inserted by its internal edge, at first, upon the oblique line which traverses the posterior surface of the tibia from above, and then, upon the internal edge of that bone, for the space of from five to eight inches, according to the individual: so that, superiorly, it is totally impossible to arrive upon the artery, without dividing this muscle. At its inferior part, this edge is free, like the whole length of the gastrocnemius muscle, in such manner, that it is easy to reach the posterior tibial artery in the lower part of the leg without wounding the muscles.

The diagnosis of the hæmorrhages furnished by a wound of the posterior and superior part of the leg, is so obscure, that I think no prudent surgeon would, in these cases, decide upon the performance of the operation of tying the opened artery. So many branches are found united in this region, that it is almost impossible to distinguish

that which furnishes the blood ; the termination of the popliteal, the commencement of the two tibial, or that of the peroneal artery may have been wounded together or separately, and all distinction thus rendered impossible. It is therefore more advantageous for the patient, to tie the crural artery, than to attempt the ligature of the trunks themselves which may have been opened. This is also the plan which must be followed in the case of diffused aneurism of the superior part of the leg ; but if the aneurismal tumour be small and it be possible to ascertain its situation upon the superior part of one of the arteries of the leg, we may try to tie these vessels above the disease.

As a general rule, I think, that the ligature of the posterior tibial artery ought not to be applied, before it has arrived at the inferior part of the superior fourth of the leg. It is too near the centre of the limb to allow of the operation being performed above that point, without danger.

This is the manner in which the operation of which we are now speaking must be performed below the superior fourth of the leg. The leg must be slightly flexed* upon the thigh, inclined outward, and laid only upon the external malleolus and the knee, so that the soft parts, by their own weight, may incline towards the fibula. The surgeon, placed to the outside of the limb, assures himself of the position of the great saphena vein, in order that he may avoid it, and then makes an incision from eight to ten lines from the inner edge of the tibia, which divides the skin alone for three or four inches. The aponeurosis of the leg must then be divided by a crucial incision. This done, he must then search for the internal edge of the gastrocnemius, and draw it towards the fibula in order to expose the soleus muscle. When this muscle is distinctly seen, all authors advise that its internal edge should be detached from the tibia, in order to arrive upon the vessels, by passing between its anterior surface and the muscles of the deep layer. But this proceeding presents two great inconveniences : at first, the difficulty of separating the soleus from the tibia,† and then, of reaching the artery which is placed at a great distance from the internal edge of that bone, so that it is necessary to traverse a narrow space, limited before by the tibia and behind by the soleus. All these difficulties are avoided by the proceeding which we have proposed ; which consists in this ; after having exposed the posterior surface of the soleus, instead of separating its internal edge from the tibia, to make an incision, from ten or more lines, to the outside of that edge, and divide the whole thickness of the soleus directly from behind forward, from its posterior to its anterior surface. After having divided the posterior

* From the general disposition of the plate, we have not been able to exhibit this position in the first figure.

† This difficulty is so great, that M. *Bouchet,* of Lyons, was obliged to cut the internal edge of the soleus across, in order to arrive upon the vessels.

aponeurosis of this muscle and a certain extent of the fleshy fibres, the lips of the wound must be separated, in order to examine the anterior aponeurosis of the muscle F. The vessels being placed immediately before it, great care must be used in making its section not to wound them. For this, the dissecting forceps must be used, and having taken hold of a small piece an opening must be made by the knife so as to allow the grooved director to be inserted beneath it: it must then be divided to the same extent as the skin: in thus dividing the soleus we possess the great advantage of falling directly upon the vessels; it only then remains to divide the thin aponeurotic layer which covers them, to arrive easily at the artery: the artery 1 is between its two veins 2. The insulation of the vessels must be done slowly, because of the thinness of the parietes of the veins and the greater facility with which they can be detached from any other part.

II. THE INFERIOR PART OF THE POSTERIOR TIBIAL ARTERY.

Below the middle part of the leg, the soleus muscle having separated from the internal edge of the tibia, the ligature of the posterior tibial artery is very much easier. In this part, it is only necessary to cut the skin, the superficial aponeurosis of the leg and that which immediately covers the vessels and the deep muscles. The artery 4, is here, rather nearer the internal edge of the tibia C, C, than superiorly. It is always accompanied by its two veins 5 and the posterior tibial nerve 6. In making the incision of the skin, care must be used to place it six or eight lines outside of the internal edge of the tibia; for without this precaution, it will not correspond with the course of the vessels, and the operation would be very difficult and much more painful to the patient. In some individuals the internal edge of the soleus is attached to the superior two thirds of the tibia; in these cases it would be necessary, to arrive upon the artery, to divide it, in the manner explained under the high operation.

It is not uncommon for the posterior tibial artery to be altogether wanting in the situations which we have pointed out; it then, follows the course of the peroneal, or rather, is found in place of that artery. In all cases, however, it is always found behind the internal malleolus to give origin to the two plantar arteries.

III. TERMINATION OF THE POSTERIOR TIBIAL ARTERY.

The posterior tibial artery 7 having arrived behind the internal malleolus, lays upon the posterior part of the sheath of the tendons of the flexor digitorum communis and tibialis posticus; it is covered by a thick aponeurosis C, and by the skin. As in the superior part it is accompanied by its two veins 8, 8, and by the posterior tibial nerve.

The position of the posterior tibial artery corresponds precisely with the middle of the space which separates the internal malleolus A from the tendo Achillis B; therefore to expose it, the incision must correspond with that point, and be about two inches in length. The skin being divided, the grooved director must be inserted beneath the aponeurosis, to protect the vessels during its section. The cellular tissue which unites the veins with the artery is very abundant; and is also much more firm and difficult to rupture than in any other part of the course of the posterior tibial artery: so that its insulation is proportionately difficult. When this is done, the artery must be surrounded by the thread, and its ligature completed.

We ought never to search for the posterior tibial below the malleolus A, because, below that point it generally terminates by giving origin to the plantar arteries.

When a wound of the sole of the foot is followed by a profuse hæmorrhage which compression cannot command, we ought in the first place to compress the pedal artery upon the dorsum of the foot and the posterior tibial behind the internal malleolus: but if this double compression cannot be supported, the ligature of both these arteries must be made, that of the posterior tibial first, and afterwards that of the pedal artery.

The surgeon must follow the same plan, in the case of an aneurism of the plantar or the termination of the pedal artery: the large anastomoses which these arteries have with each other render this double compression, or ligature absolutely necessary.

APPENDIX.

Besides the arteries, the ligature of which we have hitherto described, there are still others, upon which that operation has been performed, or proposed: such are, the aorta, ischiatic, internal pudic, epigastric, and the peroneal. As all these arteries, the epigastric excepted, are placed at a great depth, and where it would be impossible accurately to represent their position and natural relations, I thought we would here abandon the aid of figures, in order not to admit into this work any which are not faithful copies of nature. To supply however, as much as possible, this deficiency, we shall indicate the operative processes for the ligature of the vessels which we are now considering.

I. THE AORTA.

The aorta at its inferior part, occupies the anterior and left side of the vertebral column. Its bifurcation takes place between the middle and inferior part of the fourth lumbar vertebra. It is accompanied by the inferior vena cava which runs along its right side. Posteriorly, it lays upon the vertebral column; anteriorly it is covered immediately by the numerous branches of the great sympathetic nerve descending from the aortic to the hypogastric flexus, and by the fold of peritoneum which forms the left layer of the great mesentery; mediately, by the intestinal convolutions and the anterior parietes of the abdomen: so that to tie this artery, the anterior parietes of the abdomen with the peritoneum which lines them, and the peritoneum again covering the vessels must be divided. The aorta has been tied once, by Sir Astley *Cooper* for a case of inguinal aneurism which extended upwards into the iliac fossa.

The operation was performed in the following manner: the patient being laid upon the back, the head and chest elevated, the thighs flexed upon the pelvis; an incision was made from three to four inches upon the left side of the median line; the middle part of the incision slightly curved corresponded with the umbilical ring. The abdomen having been opened, and the lips of the incision separated and kept so by the intervention of the convolutions of the small intestine; it was easy to arrive upon the vertebral column, and distinguish the aorta; the peritoneum covering the vessel was then detached by the nail of the indicator finger which was then glided under the artery to serve to conduct the thread around it.

The patient survived forty hours after this operation, and, from the symptoms which were observed, as well as the alterations which were found upon opening the body, the most eminent surgeons of London agreed that death had resulted from the disease itself, rather than from the operation which had been performed. The parietes of the aneurismal tumour were so thin that it is probable that if the artery had not been tied, the hæmorrhage, which had already occurred, would have reappeared with greater violence and carried the patient off in a few moments.

Hence we may suppose that if the ligature of the aorta had been applied before the disease had made such progress, the chances of success would have been very much greater.

I have frequently performed the ligature of the aorta upon animals: in some cases they have died from peritonitis, in others, having escaped the first consequences, the heat and motion of the lower extremities reappeared about the second or third day.

II. THE INTERNAL PUDIC ARTERY.

When a harrassing hæmorrhage follows the sub-pubic operation of the stone, in order to arrest the bleeding we must employ astringents and compression within the wound itself. In a general way these means are sufficient, but as often as they are used, above all things the plugging of the wound must not be continued longer than one or two hours; but if, at the expiration of that time, the hæmorrhage reappears, where, in order to arrest it, we are obliged strongly to compress the lips of the wound, the surgeon ought then, I think, to fear the reaction which always follows the use of such irritating means, and have recourse to agents, the effects of which are less dangerous: because the space of contusion which the compression produces upon the wound always occasions it to be followed by inflammation and suppuration, which often extends upon the cellular tissue of the pelvis and causes the loss of the patient. In order to prevent consequences so formidable, it has been proposed to search for the point of the wound which furnishes the blood, and to include within a ligature a certain thickness of the soft parts; and thus the artery being comprised within the knot of the thread, may be found compressed. In one word, the mediate ligature has been advised, and often practised. The inconveniences of this mode of operation are so well known, that they need not be here pointed out: it is not less destructive than the plugging of the wound, and ought only to be used when no other method remains within our power. In the unfortunate occurrence of a profuse hæmorrhage following the operation of stone, I think, that if refrigerants and the use of moderate compression do not suffice to arrest it, we ought neither to persevere in their use, nor attempt to ligature the opened artery. It

would, in our opinion, be preferable to tie the trunk of the internal pudic artery, not within the wound but more posteriorly, in the point where it arrives at the internal side of the tuberosity of the ischium; so that although the blood may be furnished by the artery of the bulb, the superficial peroneal and the pudic itself, the hæmorrhage is always restrained.

The internal pudic artery arises from the hypogastric and escapes from the pelvis with the ischiatic by passing between the inferior edge of the pyramidal muscle and the small sacro-sciatic ligament. Immediately after, it engages between the small and great sacro-sciatic ligament to arrive at the internal side of the tuberosity of the ischium, and gains the symphysis pubis by following the ascending ramus of that bone. As soon as it arrives before the great sacro-sciatic ligament, it is united to the tuberosity of the ischium, accompanied by two veins and the nerve of the same name. All these parts are maintained against the bone by a fibrous tissue which is prolonged from the aponeurosis covering the internal obturator muscle. From this place to the skin, no organ intervenes, but adipose tissue and a few of the inferior fibres of the gluteus maximus muscle; so that in exposing this artery, there is no fear of the lesion of any important part.

The patient must be laid upon the belly, the pelvis resting upon one or two pillows; the surgeon placed on the side upon which the operation is to be made, desires an assistant to raise the buttock towards the crest of the ilium; he then makes an incision of the skin three inches in length, parallel to the direction of the tuberosity of the ischium, and so situated that its middle part shall correspond with the anterior part of the great sacro-sciatic ligament. This incision having been made he carries one finger into the bottom of the wound to ascertain the insertion of the sacro-sciatic ligament upon the ischium, and divides through some fibres of the gluteus maximus which cover that part. Then gliding his finger upon the internal surface of the ischium he perceives the pulsations of the artery which are easily distinguished in that place: having done that, he inserts the grooved director upon the course of the vessel in order to divide the fibrous tissue which covers it, and then insulates the artery from its accompanying veins and nerve. To pass the ligature, the hafted hook, with a small curve, is preferable to every other instrument.

After this operation, there is no fear of the pus infiltrating into the cellular tissue; because from its own gravity, it has always a tendency to issue from the wound. Nor need we on the other hand fear the compression and irritation of the wound caused by the position of the patient, for it is very easy to arrange some pads so that the pelvis shall only repose upon the base of the sacrum of the trochanters.

This operation seems to me, to be followed by fewer inconveniences than the long continued use of astringents, and forcible compression to suspend a hæmorrhage occasioned by the operation of lithotomy.

III. THE ISCHIATIC ARTERY.

The ischiatic artery has once been tied by Mr. *Bell* in a case of wound of that vessel. Although covered by the whole thickness of the gluteus maximus, it is not very difficult to expose the ischiatic artery, an incision from three to four inches, parallel to the fibres of the gluteus maximus, the middle part of which must correspond with the spine of the ischium will be sufficient: the artery is placed upon the base of that eminence, accompanied by the great and small sciatic nerves, and by one or two veins which are very small in comparison with the size of the artery.

IV. THE GLUTEAL ARTERY.

The gluteal artery can be tied with equal facility, the instant it issues from the pelvis, by passing between the highest part of the great sacro-sciatic notch and the pyramidal muscle. An incision of four inches, parallel to the direction of the fibres of the gluteus maximus and traversing the whole thickness of that muscle, will expose the sacro-sciatic notch. By introducing the finger to the bottom of the wound the pulsations of the artery are felt. Its insulation from the accompanying veins and nerve must be made with great management; or we shall be liable to tear the veins, their parietes being very thin.

V. THE EPIGASTRIC ARTERY.

The position of the epigastric artery in the neighbourhood of the inguinal canal and the crural ring exposes it to be opened during the operation of hernia; as well as during that of paracentesis; and from wounds of cutting instruments upon the inferior part of the abdomen. In this accident, it frequently happens that the blood passes into the abdomen; in that case, the surgeon is only apprised of it by the general signs of hæmorrhages, which are often more or less dubious; on the contrary, if the blood flow externally, the position of the wound and the quantity of the blood which escapes, are sufficient evidences for the surgeon to decide if it be furnished by the trunk, or a branch, of the epigastric artery. When a branch only is wounded, compression will generally be sufficient to arrest it: but if the trunk has been opened, the ligature will alone succeed in permanently stopping the hæmorrhage. This operation may be performed above or below the crural arch. In order to perform it above Poupart's ligament, as pointed out by *Bogros*, a transverse incision must be made, the middle part of which must correspond with the middle of the crural arch, and the skin, *fascia superficialis*,

aponeurosis of the external oblique must be divided, in order to pass between the inguinal canal and the crural arch to arrive upon the artery.

Under some circumstanees the ligature of the epigastric artery may be very easily performed below the crural arch: but in others it is very difficult and dangerous. This difference is produced by the varieties of the positions, and of the relations which this vessel presents after its origin. Generally, the epigastric forms an inflection, the convexity of which turned downwards, descends sometimes below the crural arch. In this case, the operation would be easily performed: an incision parallel to the crural arch and which divided the skin, *fascia superficialis*, and the superficial layer of the aponeurosis of the *fascia lata* would serve easily to expose the artery; but if the epigastric does not describe so decided a curve, which frequently happens, and is almost always the case in young subjects, the necessity of ascending toward the abdomen to arrive at it, renders the operation much more dangerous than when performed above the crural arch. The possibility of one such disposition I think, ought to make the first proceeding preferable to the second.

VI. THE PERONEAL ARTERY.

The peroneal like the posterior tibial artery ought never to be tied at the superior part of the leg, in the first place, because it would be difficult, in a case of hæmorrhage, following a wound of that part, to decide whether the blood is furnished by the peroneal, or by the other arteries of that region, and in the second, on account of the position of the artery it would be necessary to traverse the whole thickness of the muscles of the calf. Inferiorly, the position of this artery upon the deepest part of the interosseous ligament, renders it almost inaccessible to wounding instruments, and as it does not furnish any important branch to the foot, like the two tibial, it follows that there cannot be great difficulty in forming positive indications as to tying that artery. However if it be decided to attempt that operation, it must be recollected that the peroneal artery lays upon the posterior surface of the interosseous ligament, and is covered by the whole thickness of the flexor proprius pollicis muscle and accompanied by two veins. In order to expose it, an incision must be made parallel to the internal edge of the fibula dividing with the bistoury the insertion of the flexor proprius pollicis from that bone for the purpose of arriving upon the interosseous ligament, at the place where the artery is found. From the depth at which the artery is situated, the incision must be at least four inches long.

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